ARMY RESEARCH LABORATORY

Testing Cognitive Behavior With Emphasis on Analytical Propensity of Service Members

by Tim Bowden, Shaun Hutchins, John Jacobs, Lila Laux, and Steven Peters

ARL-CR-690 **April 2012**

prepared by

Alion Science & Technology
MA&D Operation
4949 Pearl E. Circle, #200
Boulder, CO 80301

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14. ABSTRACT

The focus of this project was to apply research and modeling to inform future development of selection criteria and mechanisms for Army intelligence analysts. Our goals were to identify the cognitive attributes required for effective intelligence analysis and quantify the relationship of individual differences in those attributes and system-level performance. Our approach included two primary efforts: (1) a review of the scientific literature and research reports and (2) development of a task network model of the all-source intelligence analyst function. The outcomes of the literature review and modeling efforts are a set of actionable recommendations that could be taken to improve the performance of the Military Occupational Specialty 35F all-source intelligence analyst.

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Executive Summary

Despite a rich and extensive history of research aimed at understanding the complexities of intelligence analysis, the processes used to turn data into actionable intelligence information, and the skills and abilities needed to perform analysis-related activities, relatively little is known about what makes an analyst successful. The increasing importance and complexity of intelligence in support of Army missions underlies a growing need to increase analysts' reliability and performance on complex, analytical decision-making tasks. To meet this need, the Army must develop a selection process that assures that prospective analysts have the required characteristics to meet the job demands.

One possible means to develop this selection process is to identify personnel characteristics that contribute to performance on mission-critical intelligence-related tasks, describe the impacts these characteristics have on overall mission performance, and then identify ways to increase the degree to which intelligence analysts possess these attributes.

The focus of this project was to begin providing the needed selection mechanism. Our goals were to identify the cognitive attributes required for effective intelligence analysis and quantify the relationship of individual differences in those attributes and system-level performance. Our approach included two primary efforts: (1) a review of the scientific literature and research reports and (2) development of a task network model of the all-source intelligence analyst function.

Rather than focusing on single-source domains, such as imagery or human intelligence, where specific cognitive attributes may be needed only for that specific discipline (e.g., visual/spatial intelligence for imagery analysts), the project focused on the multisource analyst. We believed these required attributes would be more general to suit a broad set of analytic activities within the field of Army intelligence analysis. As such, the richest target for this type of analysis appeared to be the 35F Intelligence Analyst. The Military Occupational Specialty (MOS) 35F Intelligence Analyst, or all-source intelligence analyst, is "primarily responsible for supervising, coordinating and participating in the analysis, processing and distribution of strategic and tactical intelligence."[1]

Having selected the target MOS, we began by developing a conceptual framework based on an initial review of relevant literature that would inform the search for the required personnel characteristics and their quantitative relationship to task performance. Table ES-1 presents a

[1]U.S. Army Intelligence Analyst. http://www.goarmy.com/careers-and-jobs/browse-career-and-job-categories/intelligence-and-combat-support/intelligence-analyst.html (accessed 10 September 2011).

Table ES-1. Cognitive attribute comparison approach.

Cognitive / Information- Processing Function	Initial Attributes	Selected JCAT Attributes
Core IP Function (Identify/Store Information)	S-T Memory L-T Memory Attention Management	Memorization Selective Attention
	Pattern Recognition	Time Sharing
Mediating IP Function (Manipulate Information)	Situational Awareness Problem Solving Decision Making Adaptability Creativity	Deductive Reasoning Inductive Reasoning Problem Sensitivity Flexibility of Closure Fluency of Ideas Originality
	Automaticity	
Executive IP Function (Strategy Development & Use - Involves Planning, Executing, Monitoring)	Meta-Cognition Perseverance/Resilience	**TBD**

comparison between a conceptual view based on work presented in the Army Research Institute's *Science of Human Measures Workshop*,[2] the Job Comparison and Analysis Tool (JCAT)[3] related work, and our conceptualization framed by the initial literature review efforts.

Based on this framework, we extended our literature review to identify cognitive abilities (attributes) required to perform the 35F IA job (as described in section 2.3). The attributes identified in the literature review were then validated by analyst subject matter experts at the Intelligence Center of Excellence at Fort Huachuca, AZ.

This information was then fed into a second-stage literature review aimed at identifying quantitative links between intelligence-related tasks and the specific attributes identified. The second-stage literature review began by identifying existing measures of the target attributes and using those measures to search for empirical studies that reported significant quantitative relationships between the measured attributes and performance on a task that is in some way analogous to the analyst tasks. Along with the measure-focused literature review, a task network model simulating 35F performance in Stability and Support Operations and Full-Spectrum Operations was created. The purpose of this model was to simulate the job of the 35F over a 1-year period and identify the attributes that were most frequently used or identified as most important in mission execution. The model outputs were used to hone in on specific attributes that could have the greatest potential impact on overall mission performance for the 35F.

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[2]Goodwin, G. A.; Tucker, J. S.; Dyer, J. L.; Randolph, J. *Science of Human Measures Workshop: Summary and Conclusions*; U.S. Army Research Institute Research Report 1913; Fort Benning Research Unit: Arlington, VA, 2009.

[3]Seven, S.; Akman, A.; Muckler, F.; Knapp, B.; Burnstein, D. *Development and Application of a Military Intelligence (MI) Job Comparison and Analysis Tool (JCAT)*; ARI Research Note 91–41; U.S. Army Research Institute: Arlington, VA, 1991.

The outcomes of literature review and modeling efforts are a set of actionable recommendations that could be taken to improve the performance of the MOS 35F All-Source Intelligence Analyst. These recommendations are summarized in figure ES-1, and detailed information on each recommendation can be found in section 4.

Immediate Term
IT.1 - Test for Flexibility of Closure
IT.2 - Validate critical thinking skills test for IA
IT.3 - Training for deductive reasoning
IT.4 - Explore the role of strategy development & executive IP
IT.5 - Performance Measure Identification
Mid-Term
MT.1 - Impacts of team environment on attributes
MT.2 - Further research on ability specific measures useful to selection
MT.3 - Experimental studies to identify measures with discriminant ability for IAs
MT.4 - Explore non-ability based (e.g. biographical information) measures for IA selection
Far Term
FT.1 - Trainability of IA skills
FT.2 - Neural / EEG based measures for IA abilities
FT.3 - Componential analysis of critical tasks to identify attribute/skill relationships

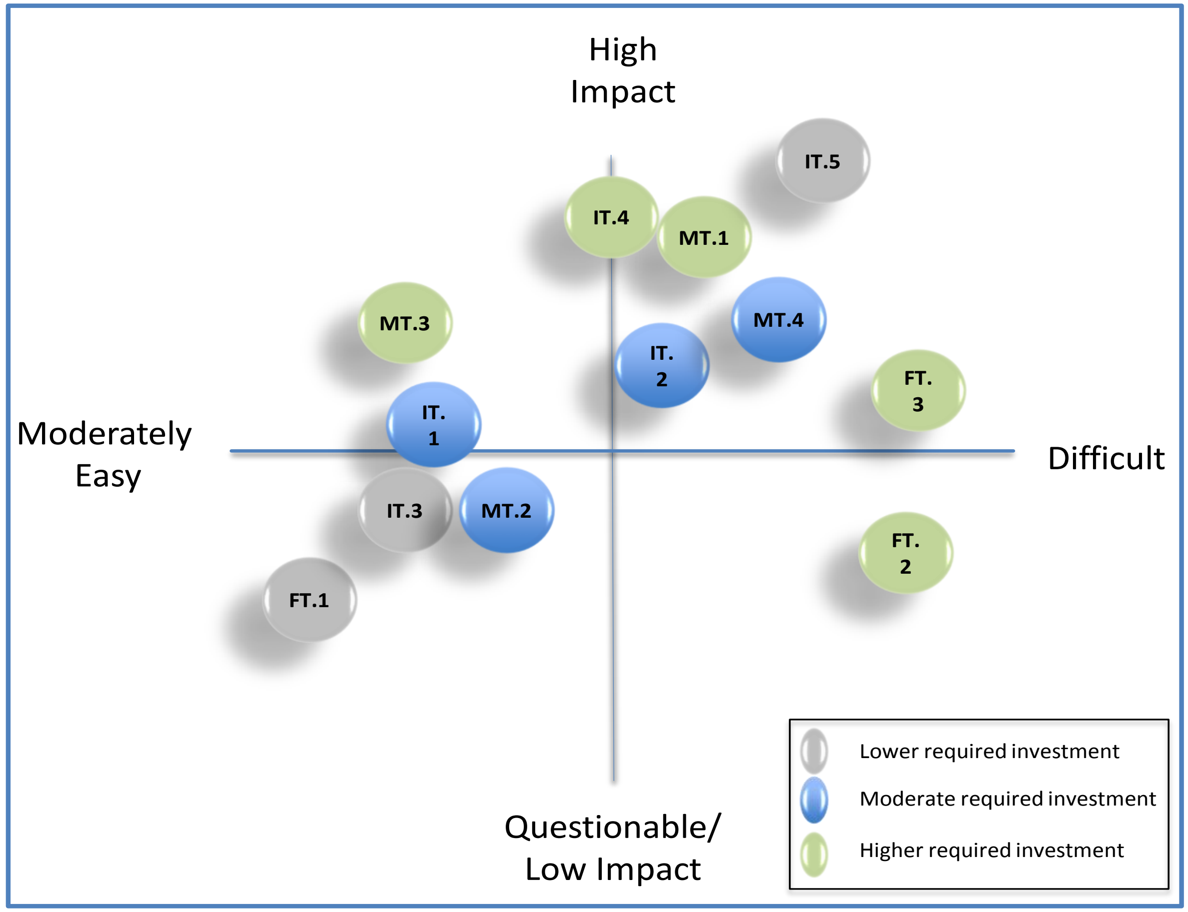

Figure ES-1. Recommended follow-on actions summary.

1. Introduction

1.1 Objective

The United States Army Operating Concept 2016–2028 (TRADOC Pam 525-3-1) (Headquarters, 2010b) highlights the need for a broad set of intelligence capabilities that are pushed down to increasingly lower levels of the Army command hierarchy. These capabilities include the need to combine traditional intelligence with emerging sources of data, such as civil affairs elements and human terrain teams. Included is the need to broaden analysis beyond military-focused intelligence to include analysis of the complexities associated with political, military, sociological, infrastructure, and informational aspects of the operating environment. The intelligence needs identified in TRADOC Pam 525-3-1 point to the increasingly important role that the collection, analysis, and dissemination of a broadening spectrum of intelligence information will have on future military operations.

The need for sophisticated all-source intelligence analysts (IAs) capable of fusing diverse sets of information into actionable intelligence is a common theme in the literature on intelligence analysis. Along with TRADOC Pam 525-3-1, researchers such as Allen (2008), Hutchins et al. (2004; 2007), Fingar (2011), Krizan (1999), and Treverton and Gabbard (2008), among others, describe a complex environment characterized by vast amounts of information and complex, changing relationships that must be collected, analyzed, and understood in order to maintain intelligence superiority. The increasingly complex environment where IAs must operate highlights the need to reexamine what it takes to successfully perform this critical role for Army units. The goal of this effort was to identify key cognitive attributes required to successfully perform intelligence analysis tasks, demonstrate a simulation-based approach for understanding the impact of these attributes on overall performance, and develop a set of actionable recommendations to improve analyst performance through selection, training, or capability development activities in the immediate, near, and far terms.

1.2 Background

Despite a rich and extensive history of research aimed at understanding the complexities of intelligence analysis, the processes used to turn data into actionable intelligence information and the skills and abilities needed to perform analysis-related activities, relatively little is known about what makes an analyst successful. Indeed, Lowenthal notes, “We have not yet (after more than 55 years) come up with a good picture in our minds—nor have we successfully enunciated—just what a professional intelligence analyst ‘looks like,’ and how we train and develop this analyst across his or her entire career—not just at the outset” (Swenson, 2003). This lack of a common understanding of the set of core competencies (Lewis, 2005) that analysts must possess to successfully perform their tasks presents significant challenges to efforts aimed at improving the accuracy, timeliness, and usefulness of intelligence products. The increasing importance and complexity of intelligence in support of Army missions underlies a growing need to increase analysts' reliability and performance on complex, analytical decision-making tasks. To meet this need, the Army must develop a selection process that assures that prospective analysts have the necessary knowledge, skills, and abilities (KSAs) to perform this complex task.

One possible means to provide this selection process is to identify personnel characteristics that contribute to performance on mission-critical intelligence-related tasks, describe the impacts these characteristics have on overall mission performance, and then identify ways to increase the degree to which IAs possess these attributes.

The focus of this project was to begin the process of providing the needed selection mechanism. In order to accomplish this aim, the project had the following objectives:

- Determine the critical tasks that all-source IAs perform.
- Identify the personnel characteristics (i.e., skills and attributes) needed to perform as well as IAs.
- Identify ways to assess performance on those predictor skills and attributes.
- Perform research to quantify potential performance improvements associated with variance in the identified attributes.
- Use modeling to evaluate the impact on total system performance.

This report describes the approach taken to accomplish these objectives, the results of the project, and a series of recommendations for immediate, near-, and far-term activities to improve analyst performance by leveraging the work completed on this effort.

1.3 Approach

Our goals were to identify the cognitive attributes required for effective intelligence analysis and quantify the relationship of individual differences in those attributes and system-level performance. Our approach included two primary efforts: (1) a review of the scientific literature and research reports and (2) development of a task network model of the all-source IA function. The literature review was used to identify the cognitive attributes that are characteristic of successful analysts (i.e., what the successful analyst "looks like") and to identify quantitative relationships between those cognitive attributes and performance on tasks that are similar to the tasks of Army IAs.

At the outset of the project, the team conducted an initial literature search in the areas of cognitive readiness, decision making, general intelligence theory, and military and other governmental intelligence processes. A second literature review was focused on the cognitive attributes that had been identified as important to IA performance in previous research (Knapp and Tillman, 1998) and that were confirmed during subject matter expert (SME) interviews.

Appendix A contains the full set of literature we reviewed as part of this project effort. The results of these literature searches formed the basis for identifying the initial set of cognitive attributes identified as predictive of successful performance in intelligence analysis tasks. A summary of the literature reviewed and the resulting list of the key personnel attributes of successful analysts are detailed in section 2.1 of this report.

Along with identifying the cognitive attributes of effective analysts, we set out to determine the specific intelligence analysis discipline that should be the focus of this effort. Because of the variety of disciplines and activities that fall under the umbrella of intelligence analysis and the corresponding diversity of skill sets that may be required to perform those tasks, this effort needed to be focused on a set of exemplar tasks and skill requirements that would be most generalizable across the spectrum of analysis domains. Rather than focusing on single-source domains, such as imagery (IMINT) or human intelligence (HUMINT), where specific cognitive attributes may be needed only for that specific discipline (e.g., visual/spatial intelligence for imagery analysts), the project focused on the multisource analyst. We believed these required attributes would be more general to suit a broad set of analytic activities within the field of Army intelligence analysis. As such, the richest target for this type of analysis appeared to be the 35F IA. The Military Occupational Specialty (MOS) 35F IA, or all-source IA, is "primarily responsible for supervising, coordinating and participating in the analysis, processing and distribution of strategic and tactical intelligence" (U.S. Army, 2011). 35F duties include the following:

- Prepare all-source intelligence products to support the combat commander.
- Provide support to the Intelligence, Surveillance, and Reconnaissance (ISR) synchronization process.
- Receive and process incoming reports and messages.
- Assist in determining the significance and reliability of incoming information.
- Establish and maintain systematic, cross-reference intelligence records and files.
- Integrate incoming information with current intelligence holdings and prepare and maintain graphics.
- Conduct Intelligence Preparation of the Battlefield (IPB) using information from all sources (U.S. Army, 2011).

Because of the broad nature of the all-source IA's tasks and the requirement for the analyst to examine a broad spectrum of data and transform it into useful information for battlefield intelligence, the project team, in conjunction with the Intelligence Center of Excellence, chose the MOS 35F as the target of detailed analysis under this effort.

Part of our approach focused on the use of discrete event simulation as a means of evaluating analyst performance employing an approach derived from the human performance simulation methods found in the Improved Performance Research Integration Tool (IMPRINT). IMPRINT uses an embedded task taxonomy to describe the demands (taxons) that task performance places on operators completing mission-related tasks. The taxons provide a generalizable method for describing tasks in terms of their component demands so that environmental factors and personnel characteristics can influence task performance based on defined performance shaping algorithms that are derived from validated literature or experimental data collections. For this effort we used the IMPRINT simulation engine, Micro Saint Sharp, to create a basic model of the tasks required to conduct activities related to the high-level analyst function of "Evaluate the Threat." Micro Saint Sharp was employed so that the modeling could access more of the functionality that underlies IMPRINT, but it is not accessible directly in the IMPRINT environment. In the model created for this effort, we applied the cognitive attributes identified from the literature search, in a manner analogous to the resident taxons in IMPRINT, to describe the task demands placed on the 35F. A description of the model is in section 2.5 of this report.

2. Method

2.1 Cognitive Attribute Research

A key component of this effort was an extensive review of existing literature that could be relevant to understanding the intelligence analysis activities and the personnel attributes required to successfully perform these activities. The study team conducted a three-part review that included an effort aimed at understanding the intelligence analysis domain and required activities, research on the cognitive attributes that lead to success in these activities, and finally on methods for measuring the attributes and quantifying the relationship between those measures and analyst performance.

As noted previously in this report, a number of publications attempt to describe the job of an IA and the processes undertaken to translate raw data into actionable intelligence information. A universal theme across the literature reviewed for this effort was that the job of an analyst is varied, complex, and, with the explosion of available information, requires a highly skilled individual to make sense of the available data. One of the key pieces of literature reviewed in the effort to understand the tasks and jobs of military IAs was the work of Seven et al. (1991) that developed the Job Comparison and Analysis Tool (JCAT). The JCAT was developed by the Army Research Institute (ARI) to assess the importance of various abilities to the activities performed by an IA (96 series of Military Occupation Specialty - Intelligence MOSs). The attributes that these researchers employed to identify the personnel characteristics associated with "good" IA performance were derived from the Manual for the Ability Requirements Scales (MARS), which was developed by Fleischman (1991; 1992; Fleischman and Quaintance, 1984).

The work to develop the JCAT provided two key elements for the current effort. First, the personnel attributes identified provided a validation reference for the characteristics derived from other literature sources. Second, additional work that grew out of JCAT development provided insight into the specific critical tasks for an all-source analyst. Specifically, Knapp and Tillman (1998) evaluated IA MOSs using JASS (the computerized version of JCAT). Their task analysis of the 96B MOS determined that the following were the "critical tasks" for that MOS:

- Assess incoming information
- Determine information gaps
- Develop a doctrinal template
- Develop a situation template
- Develop an intelligence briefing
- Develop the SITMAP
- Identify high-payoff targets
- Other
- Perform interactive input processing
- Predict potential military operations

From the Knapp and Tillman work, in conjunction with literature descriptive of the IA tasks and SME input, we selected the following tasks as being representative of the critical tasks performed by 35F all-source analysts:

- Analyze map data
- Determine information gaps and discrepancies
- ID potential targets
- Maintain the situation map
- Evaluate the threat
- Perform situation development
- Define the operational environment
- Describe environmental effects on the threat and friendly ops
- Conduct fusion of information from multiple intelligence sources

2.1.1 Initial Literature Review

The second element of the literature review was associated with identifying the cognitive attributes that are descriptive of a successful analyst. The rationale for the starting point for this initial review was based on our conceptualization of potentially useful cognitive theory and research focused on information processing (IP) as a key enabler for analysis, reasoning, and decision making. The initial list of cognitive attributes was derived from our preliminary review of previously connected efforts that were similar but not of the same domain. Of specific interest was a recent ARI research report describing the results of a workshop involving the science of human measures (Goodwin et al., 2009). This report advocated focusing on three broad cognitive attribute areas when searching for ways to enhance personnel assessment, training, and professional development: What Soldiers "can do," "want to do," and "will do." The report also advocated looking into factors and processes related to "mental agility" and other related problem-solving capabilities (see Goodwin et al., 2009, pp 19–21). This preliminary review led the study team to conduct an initial literature review that looked at relevant theory-driven cognitive/IP research, as well as recent advances in cognitive neuroscience research related to electroencephalogram (EEG) mapping. The most notable theoretical approach was that provided by Robert Sternberg's Triarchic Theory of Intelligence (1985; 1999), which included promising but limited empirical results indicating that component IP activities can be isolated and measured and can predict performance on more complex cognitive activities, such as reasoning and decision making.

The results of this literature search lead to other potentially useful areas of cognitive theory and research, including neural activity (EEG) mapping and Cognitive Load Theory (CLT). The reasons for reviewing these areas were threefold: (1) the notion of metacognition, or knowledge about one's cognitive processes, has received a great deal of attention by cognitive theorists and those studying strategic thinking, (2) while cognitive attributes have traditionally been measured solely through one of a wide variety of intelligence (cognitive) ability tests, EEG mapping offered more direct evidence of cognitive processing activity and ability, and (3) mental effort as a potential indicator of advanced (cognitive) strategy use is one area of research thought to have relevance for this project.

A brief summary of the findings from each of these major areas of the literature review follows. A more extensive discussion of the initial attribute-focused literature review can be found in appendix B.

Sternberg's Triarchic Theory of Intelligence (1985; 1999) and its associated Componential Analysis approach provide an interesting and potentially useful view of human problem solving (Laux and Lane, 1985). Specifically, intelligent behavior and associated problem-solving ability is viewed in terms of IP components, and there is evidence showing IP differences are related to differences in performance on cognitive tasks.

Studies using neural activity (EEG) mapping have demonstrated a relationship between specific neurological activity and short-term (working) memory and other strategic (cognitive) functioning (Forstmann et al., 2011). This relationship can be used to predict performance on complex tasks.

CLT (Chandler and Sweller, 1991) views mental "effort" in terms of demands on working memory and an indicator of cognitive-processing capability and efficiency. One approach to measuring CLT involves having subjects perform two tasks simultaneously (Paas et al., 2003; Van Merriënbohr and Sweller, 2005). This "dual task" methodology is problematic because of its inability to definitively determine what specific cognitive component(s) are being measured. However, the study team recognized that there was a possibility of combining EEG mapping with CLT methodologies to more accurately explore the notion of mental effort as an indicator of IP efficiency.

By combining what was learned from related studies (e.g., Goodwin et al., 2009; Knapp and Tillman, 1998; Seven et al., 1991) with insight gleaned from the initial attribute–focused literature search, we developed a list of potentially important cognitive attributes for further study. Table 1 presents a comparison between a conceptual view based on work presented in the ARI's *Science of Human Measures Workshop* (Goodwin et al., 2009), the JCAT-related work, and our conceptualization framed by the initial literature review efforts.

Table 1. Cognitive attribute comparison approach.

Cognitive / Information- Processing Function	Initial Attributes	Selected JCAT Attributes
Core IP Function (Identify/Store Information)	S-T Memory L-T Memory Attention Management	Memorization Selective Attention
Mediating IP Function (Manipulate Information)	Pattern Recognition Situational Awareness Problem Solving Decision Making Adaptability Creativity	Time Sharing Deductive Reasoning Inductive Reasoning Problem Sensitivity Flexibility of Closure Fluency of Ideas Originality
Executive IP Function (Strategy Development & Use - Involves Planning, Executing, Monitoring)	Automaticity Meta-Cognition Perseverance/Resilience	**TBD**

The cognitive abilities (attributes) required to perform the 35F IA job were identified based on the literature and SME input (as described in section 2.3). The attributes determined as required to perform critical 35F tasks were as follows:

1. Memorization
2. Selective attention
3. Time-sharing
4. Deductive reasoning
5. Inductive reasoning
6. Problem sensitivity
7. Flexibility of closure
8. Fluency of ideas
9. Originality

SMEs subsequently identified *perseverance* as a tenth attribute of importance to add to this list.

The final element of the literature review was focused on identifying studies where these critical attributes had been assessed and where they were used to predict performance on tasks that were related to the critical tasks just listed.

2.1.2 Attribute Literature Review

The final aspect of the literature review conducted for this effort was a formal two-part literature search guided by the attributes derived from the literature and later validated by SME consensus, as important for IA performance. This effort represents the primary focus of the overall project and was aimed at understanding both how personnel attributes can be measured and how the attributes can be quantitatively linked to performance on IA activities. To establish this quantitative link between attribute levels and analyst task performance, a meta-analytic approach was used targeting correlational studies examining the relationship between scores on standardized tests measuring the attributes and performance on experimental tasks or tests that share characteristics similar to intelligence analysis tasks.

We began by reviewing the *Mental Measurements Yearbook* (Spies et al., 2010) for standardized tests related to the personnel attributes of interest. Pertinent synonyms for each attribute of interest were generated for keyword searches. For example, to identify studies measuring the attribute "originality," search terms included "originality" and "creativity," and for "fluency of ideas," search terms included "fluency of ideas" and "ideational fluency." The list of attributes and alternate key words was used to identify measures in the *Mental Measurements Yearbook* where any of the keywords appear in the test name, test purpose, or test index. This search generated a list of available standardized tests that measure the cognitive attributes required for successful IA performance. A full list of the standardized tests by attribute is provided in appendix C.

The list of standardized tests used to either partially or wholly measure the attributes that had been identified as important to IA performance allowed us to target the next round of literature searches on empirical studies referencing the specific standardized tests, which were likely to have measured the personnel attribute as a covariate to some performance measure of interest. Only studies that tested normal adult populations resembling IA personnel were examined further. Search results were excluded if the population was specific to young children or older adults, or if the primary purpose was diagnosis of deficiencies in the attribute.

We utilized the database services of EBSCO Publishing to search seven relevant databases: Academic Search Premier, Business Source Premier, CINAHL, ERIC, PsychARTICLES, PsychINFO, and Social Sciences Abstracts. All standardized tests identified for each attribute were individually searched in “all text,” and the results were saved by test name. Results were then reviewed for relevance and to ensure they met the following set of requirements:

- The study must report the test used for measurement of attributes.
- The study must report the experimental task, test, or activity also performed by the participants.
- The study must report a measure of the relationship (preferably Pearson product moment) between measured quantity of an attribute and measured performance on the experimental task.

By filtering the search results based on these criteria, we identified a subset of the available literature for the meta-analytic review. This subset of literature was then mined for quantitative performance relationships. An Excel dataset was created to record the following information for each included study:

- The full citation
- Attribute measured (i.e., deductive reasoning)
- The measurement instrument (i.e., Cornell Critical Thinking Test)
- A description of test correlate (i.e., experimental problem-solving task)
- The type of effect measure (i.e., d’, t, r, etc.)
- A conversion of the test static to r
- The group sample size of the study

The contents of the MS Excel spreadsheet provided the basis for establishing effects relevant to predicting performance on IA tasks from performance on standardized attribute measures.

However, translating the data in this raw form into something that could be incorporated into our model (and modeling environment) was complex. Our modeling environments use a task demand approach to build subtask networks. The performance relationships from the literature were in raw experimental task form, not in task demand composition format. Consequently, each test correlate that standardized test scores had been regressed upon in the studies was characterized in terms of the task demand taxonomy as might be done by a modeler attempting to model the experimental tasks. A 10-task demand taxonomy based on the 10 IA attributes was used to characterize experimental tasks. This step required the team to make subjective but informed judgments about the task demands that best described the experimental tasks. It ultimately allowed us to translate the raw effects presented in the literature into an initial set of data comprising sets of associated concepts that already existed in our modeling environments, i.e., personnel attribute or standardized test scores and task "taxons" or the experimental tasks characterized by taxons. The resulting data set consisted of correlations between attributes and typologies of task demands.

2.1.3 Task Typology and Attribute Relationship to Task Taxon Demands

Once the task demand mapping was complete, we were confronted with the issue of whether or how to reduce the identified effects/relationships into a one-to-one attribute to taxon relationship. For example, say *hypothetically* that every experimental problem-solving task was characterized with deductive reasoning (DR), organization of information (OI), and memory (M) taxons. This results in problem-solving tasks being characterized by a DR-OI-M typology of taxons. Furthermore, if we identified six studies in the literature that correlated a standardized test of flexibility of closure (FC) with "problem-solving" task performance, then we could compute the mean correlation between FC and the DR-OI-M typology. If this performance effect was embedded in the modeling environment, then whenever a task was modeled and characterized by DR, OI, and M taxons, we could assume to know the approximate nature of the relation between an individual's FC ability and that specific modeled task's performance.

Typically, discrete event simulation modeling tools such as Micro Saint Sharp and IMPRINT want the personnel attribute-to-task relationship to be represented at a more granular level than a taxon typology; and consequently, there is the desire to further reduce the attribute-to-task relationship to the individual taxon level. Because we are starting with mean correlation coefficients, these reductions to individual taxons are confronted by issues of (multiple) colinearity because we do not know whether the taxons that characterize a task are all contributing to task performance, and if so, how much each contributes, and whether their individual contributions are intercorrelated. For example, if both inductive reasoning and deductive reasoning ability predict performance on the Evaluate the Threat task, we must ask whether their contribution is independent (additive) or does either of them predict performance on Evaluate the Threat performance as well as including both of them as predictors? The issue of multicollinearity exists both for the task typologies (when a whole task is modeled at the subtask level with a typology and then recombined) and when tasks are described by multiple taxons (whenever tasks and subtasks are modeled with a combination of taxons). Because of these issues, we chose not to make the assumptions necessary for the singular taxon reduction and instead chose to leave the tasks at the typology level of task demand characterization.

Following the general meta-analytic approach for meta-analysis of correlation measures in Borenstein et al. (2009), the dataset was analyzed using Comprehensive Meta Analysis software (http://www.meta-analysis.com/). Here, the correlation coefficient (r) and number of study participants (n) were transformed to Fisher's Z, and summary effects and standard error (SE) were computed for each demand typology within individual personnel attributes. The results were compiled into an attribute by task demand typology matrix (see appendix D).

2.2 Key Cognitive Attributes/Abilities

Abilities and aptitudes are cognitive or mental characteristics or attributes that affect the potential to learn or to perform. Cognitive abilities can be thought of in broad terms (e.g., intelligence) or in terms of specialized abilities, such as verbal, spatial, memory, reasoning, problem solving, and psychomotor ability. Aptitudes may be more broadly conceptualized than abilities and may include any number of individual-differences factors, such as motivation, that influence the likelihood of performing successfully. In 1984, Fleischman described tasks in terms of performance taxonomies that include both abilities and aptitudes (Fleischman and Quaintance, 1984).

ARI developed JCAT in order to identify MOS capabilities and Intelligence Electronic Warfare (IEW) system demands "in terms of abilities, skills, and intelligence production activities" (Seven et al., 1991). The origin of the list of ability requirements from which the abilities in the JCAT were derived was MARS, which was developed by Fleischman (1991; 1992; Fleischman and Quaintance, 1984) and ARI. The MARS list of abilities has been widely used and validated (Seven et al., 1991). The ARI research included 50 abilities from the Fleischman list of abilities that they considered to be potentially important to IAs (see table 2 for the list of abilities included in the JCAT).

In order to reduce the list for the current study to those attributes that were deemed important to all-source IAs, we selected only those abilities that were selected by eight or nine (of nine) IAs in the Seven et al. (1991) study as being an important attribute of the 96B (now 35F) IA job, or which were rated by the nine 96B experts as greater than four (of seven) in importance to the IA task. This resulted in a list of 20 attributes that we considered relevant to performance of the all-source 35F IA position and which could be assessed using a cognitive ability test. The ratings from the Seven et al. (1991) study are shown in table 2 where aptitudes in red were not

Table 2. Aptitudes from the JCAT that were assessed in the Seven et al. (1991) study.

Aptitude/Ability for 96B (35F)	**Named by Eight or Nine SMEs or Rated Importance 4 or >4 (red = <8 SMEs)**	**Rated Importance to Job of 7 (Mean/SD)**
Oral comprehension	9	5.9/1.0
Written comprehension	9	6.4/0.8
Oral (speech) expression	9	6.2/0.8
Written expression	9	6.0/0.9
Memorization	9	5.6/1.5
Problem sensitivity	9	5.1/1.6
Originality	8	4.8/1.3
Fluency of ideas	9	4.8/2.2
Flexibility of closure	8	4.9/2.1
Selective attention	8	5.3/1.5
Spatial orientation	9	5.2/1.4
Visualization	9	5.8/1.4
Inductive reasoning	8	5.3/1.7
Category flexibility	6	5.2/1.8
Deductive reasoning	9	5.9/1.3
Information ordering	8	5.0/1.7
Math reasoning	7	4.5/1.7
Number facility	8	3.9/1.7
Time sharing	8	5.8/1.2
Speed of closure	8	5.5/2.1
Perceptual speed and accuracy	7	4.4/1.8
Near vision	6	4.3/1.9
Far vision	6	4.1/1.7
Visual color discrimination	7	4.2/2.0
General hearing	7	4.1/1.7
Auditory attention	6	5.0/0.6
Finger dexterity	8	4.7/1.4
Manual dexterity	6	4.8/1.1
Arm-hand steadiness	6	4.5/11.8
Multi-limb coordination	5	4.1/1.9
Extent flexibility	6	4.1/1.8
Cross body coordination	6	4.2/1.9
Static strength	7	4.0/1.4
Trunk strength	4	4.0/2.2
Stamina	6	4.3/2.5

rated as important by eight or nine analysts in the expert group, but importance was rated >4 by the remaining experts. This list was mapped against our initial conceptual attributes list based on other intelligence-related efforts and our review of the literature surrounding theories of human intelligence (e.g., Sternberg's theories), innovations in EEG measurement of cognitive attributes, and cognitive load theory as previously described. Because of the high degree of conceptual overlap between our initial list and that generated from the work of Seven et al., we elected to use the attributes from the JCAT work because of the rigorous psychometric validation effort that was undertaken on the JCAT.

Based on these analyses and the criterion that the aptitude should be measurable by a cognitive test, we selected the following 20 aptitudes as those that we believed could be assessed for use as predictors of IA performance.

Definitions of cognitive attributes from MARS:

1. Oral Comprehension: The ability to listen to and understand words and sentences.
2. Written Comprehension: The ability to understand written words, sentences, and paragraphs.
3. Oral Expression: The ability to use words or sentences in speaking so that others will understand.
4. Written Expression: The ability to use words or sentences in writing so that others will understand.
5. Memorization: An ability to remember information such as words, numbers, pictures, and procedures.
6. Problem Sensitivity: The ability to tell when something is wrong or is likely to go wrong. It does not involve solving the problem, only recognizing there is a problem.
7. Originality: The ability to produce unusual or clever ideas about a given topic or situation. It is the ability to invent creative solutions to problems or develop new procedures for situations in which standard procedures do not apply or are not working.
8. Fluency of Ideas: The ability to come up with a number of ideas about a topic (the number of ideas is important, not their quality, correctness, or creativity).
9. Flexibility of Closure: That ability to identify or detect a known pattern (a figure, object, word, or sound) that is hidden in other distracting material.
10. Selective Attention: The ability to concentrate on a task over a period of time without being distracted.
11. Spatial Orientation: The ability to tell where you are in relation to the location of some object or to tell where the object is in relation to you.
12. Visualization: The ability to imagine how something will look when it is moved around or when its parts are moved or rearranged. It requires the forming of mental images of how patterns or objects would look after certain changes, such as unfolding or rotation. One has to predict how an object, set of objects, or pattern will appear after the changes are carried out.

13. Inductive Reasoning: The ability to combine pieces of information to form general rules or conclusions (includes finding a relationship among seemingly unrelated events).

14. Deductive Reasoning: The ability to apply general rules to specific problems to produce answers that make sense.

15. Category Flexibility: The ability to produce many rules so that each rule tells how to group a set of things in a different way. Each different group must contain at least two things from the original set of things.

16. Information Ordering: The ability to follow correctly a rule or set of rules to arrange things or actions in a certain order. The rule or set of rules must be given. The things or actions to be put in order can include numbers, letters, words, pictures, procedures, sentences, and mathematical or logical operations.

17. Mathematical Reasoning: The ability to understand and organize a problem and then select a mathematical method or formula to solve the problem. It encompasses reasoning through mathematical problems to determine appropriate operations that can be performed to solve problems. It also includes the understanding or structuring of mathematical problems. The actual manipulation of numbers is not included in this ability.

18. Number Facility: Involves the degree to which adding, subtracting, multiplying, and dividing can be done quickly and correctly. These can be steps in other operations like finding percentages and taking square roots.

19. Time Sharing: The ability to shift back and forth between two or more activities or sources of information (such as speech, sounds, touch, or other sources).

20. Speed of Closure: Involves the degree to which different pieces of information can be combined and organized into one meaningful pattern quickly. It is not known beforehand what the pattern will be. The material may be visual or auditory.

From this list, the following nine attributes were selected, based on SME input, as being critical for IA performance:

- Memorization
- Time-sharing
- Inductive Reasoning
- Flexibility of Closure
- Originality
- Selective Attention
- Deductive Reasoning
- Problem Sensitivity
- Fluency of Ideas

These nine key attributes were used to describe both the tasks a 35F all-source analyst performs in support of mission objectives and the individual who performs the tasks. That is, each task the analyst performs requires one or more of the nine attributes, and the degree to which the individual performing that task possesses a sufficient quantity of the required attribute(s) impacts his or her ability to perform the task.

2.3 Tasks of an All-Source Intelligence Analyst

In order to quantify the relationship between attribute levels and task performance, we needed to understand the intelligence analysis process, the tasks that compose this process, and the characteristics of the demands of the tasks in terms of analyst aptitude. To develop this understanding, we reviewed Army doctrine, manuals, and training related publications to validate the critical tasks of the 35F as initially identified through literature review.

Field Manual 34-3, *Intelligence Analysis*, states that an IA converts combat information into intelligence by following a four-step process: observation, assessment, analysis, and synthesis (Headquarters, 1990). Field Manual 2-0, *Intelligence*, defines analysis as “the process by which collected information is evaluated an integrated with existing information to product intelligence that describes the current – and attempts to predict the future – impact of the threat, terrain and weather, and civil considerations on operations” (Headquarters, 2010a). According to Land (2004), four analytical tasks make up the analysis and synthesis process:

1. Identify the problem
2. Conduct background research
3. Identify intelligence production requirements and options
4. Request information

As Land (2004) notes, FM 34-3 describes a set of dynamic and interactive analytical skills needed by IAs:

1. Understanding the analytic objective—understanding the desired end-state of reaching a predictive conclusion about the threat.
2. Establishing the baseline—the analyst collects and organizes the pertinent facts about a given situation or problem.
3. Formulating the hypothesis—the analyst develops hypotheses to account for any information gaps and questions resulting from a review of the baseline information regarding the environment, its effects, and the threat. The analyst ensures that his hypotheses address the correct problem.
4. Testing the hypothesis—the analyst will either confirm or deny his hypothesis by developing observable indicators that can be collected.

5. Recognizing uncertainties—an IA’s primary mission is to decrease uncertainty by confirming or denying hypotheses about the environment or threat.

The 35F MOS designates the all-source IA. FM 2-0 (2010a) defines all-source intelligence as “[t]he intelligence discipline concerned with all-source products and the processes used to produce them.” “Analysis is achieved through the reduction of information to its basic components. Each of these components is then examined to determine its nature, proportion, function, and interrelationships. . . . The analyst examines, assesses, and compares bits and pieces of raw information, and then synthesizes those findings into an intelligence product reflecting an adversary’s capabilities and vulnerabilities. Most intelligence analysis is predictive in nature . . .” (FM 34-130 Draft 2000, 2-1 as cited in Land, 2004).

In order to accomplish the high-level intelligence analysis goals described by these field manuals, the 35F MOS IA performs a set of discrete tasks. These tasks were identified in training course–related materials provided by the Intelligence Center of Excellence in support of this project effort and from relevant literature. A Personnel Supervision and Management (PS&M) list of the 35F Skill Level Tasks and a Skills Crosswalk (35FCrosswalkCTLAnalysisDIF29JAN10a.xls) was provided to the research team. From these materials, the set of specific tasks performed by the analyst was identified.

In order to define the research effort for this project and focus the modeling effort, the team needed to identify a prioritized list of analyst tasks to be the subject of a further detailed analysis. In order to accomplish this we leveraged the difficulty, importance, and frequency (DIF) ratings provided as part of the Skills Crosswalk document. By averaging the ratings, we were able to develop a priority metric for the tasks. The list of tasks was then compared to the tasks listed in other documents to identify common elements between the task lists.

One highly rated task that appeared in all documents was the Evaluate the Threat activity. Given the commonality of this task across all provided materials, its importance based on DIF ratings, and the obvious analytic nature of the task, we elected to use it as the basis for our modeling and continued research efforts. The detailed subtasks that make up this task and the data collected from SMEs on task performance were captured in the model and are described later in this report.

In order to identify the specific attribute requirements for successful performance as an analyst, the team needed to map the specific attributes required for task performance to the tasks that analysts perform. A number of researchers have analyzed the KSA requirements associated with the IA job. Knapp and her colleagues (Knapp and Tillman, 1988; Seven et al., 1991) described the IA functions and tasks using Fleishman’s task taxonomy and developed a tool for determining which KSAs are associated with specific IA jobs. The resulting tool, the JCAT, was developed to identify MOS capabilities and IEW system demands in terms of abilities, skills, and intelligence production activities. The JCAT was subsequently used to collect abilities and skills data for the seven MOSs comprising what is now the 35 MOS group of IAs.

In an effort to validate the tasks derived from the PS&M documentation, we revisited a number of publications, including FM 2-0 *Intelligence* (2010) and FM 34-3 *Intelligence Analysis* (1990), which describe the intelligence process performed by the IA in detail. Additionally, Krizan (1999) defined the KSAs that describe the IA job while Heuer (1999) and others have addressed the psychological issues associated with IA performance, such as perception, memory, and cognitive biases. Other authors have described the task of IA as a means of assisting analysts to perform their jobs more effectively (e.g., Clawson, 2008; Connors et al., 2004; Land, 2004). We compared these publications with tasks derived from the training-related materials provided by the Intelligence Center of Excellence and information contained in the JCAT. The results of this comparison are shown in table 3. There was considerable agreement among these experts and the other authors just cited concerning what comprises the IA job. Based on these analyses, and those previously described, we accepted the 12 tasks in the job description from the 35F crosswalk duty table as representative of the critical functions/tasks performed by the 35F.

Table 3. 35F task crosswalk.

301-35F-xxx-SK Modified Duty	**35F Crosswalk**	**Duties/JCAT**	**Duties Intelligence Essentials for Everyone (Krizan)**
Define the operational environment	IPB; Planning (353F40 only)	Planning; set up, maintenance, preparing	—
Describe environmental effects on threat and friendly operations	Analysis; Advance map reading; IPB	Analyze/exploit data	Data monitoring; Data collection Data analysis
Evaluate the threat	ISR; Analysis	Collect data; Analyze/exploit data	Data monitoring; Data collection Data analysis
Determine threat courses of action	ISR; Analysis; Targeting	Interpret data	Data analysis
Perform situational development	ISR; Analysis; IPB	Interpret data	Data analysis
Present intelligence findings	Reports and dissemination	Disseminate data	Data interpretation/ communication
Draft ISR synchronization products	ISR; Analysis	Prepare outputs	Data analysis
Develop ISR synchronization products	ISR; Analysis	Prepare outputs	Computer utilization
Perform ISR synchronization	ISR; Analysis	Prepare outputs	Computer utilization
Integrate ISR synchronization	ISR; Analysis	Prepare outputs	Computer utilization; coordination
Provide intelligence support to targeting	Reports and dissemination	Disseminate data	Data interpretation/ communication; coordination
Provide intelligence support to training	Provide intelligence to combat assessments; reports and dissemination	Disseminate data	Coordination

2.4 Subject Matter Expert Data Collection

Having identified the attributes we believed to be characteristic of a successful IA from the literature review effort and selected a target analyst task for analysis, we then interacted with IA SMEs to confirm our initial findings and collect the data needed to move on to the next phase of the project. Two members of the study team held interviews with intelligence analysis SMEs at the U.S. Army Intelligence Center at Fort Huachuca, AZ, on 12–14 July 2011. The primary objectives were to (1) identify and then further decompose one or more 35F (all-source IA) tasks in order to focus the modeling effort, (2) confirm the relevance of the nine cognitive attributes previously identified as critical for performing their associated job-related tasks, and (3) use the decomposed 35F task(s) to determine the degree to which these attributes get employed by an analyst when completing the task(s).

Over the course of the interviews, the study team interacted with four senior IA SMEs. The overall plan of action by the study team was to revalidate that the nine cognitive attributes were still relevant for completing 35F job tasks and to identify other relevant attributes the SMEs considered to be critically important for successful performance. The study team worked with the SMEs to identify one or two tasks considered to be of high interest and representative in terms of their inherent utilization of cognition-relevant skills, such as analysis, reasoning, and decision making.

Once one or two tasks of primary interest were identified, the study team worked with the SMEs to decompose the primary interest task(s) in order to determine important task characteristics. These characteristics included (1) what constituted successful, as well as subpar, performance for a given task or task element; (2) how long did a task normally take to complete; and (3) what interdependencies existed between tasks. To the extent possible, example situations were elicited from the SMEs as a means for both the SMEs and the study team members to explore the task characteristics in further detail. These characteristics were important for developing a useful exploratory model for this project. The manner in which these tasks were constructed into the human performance model developed for this effort is described in section 2.5, and the detailed task information can be found in appendix E of this report. At no time during the interview process did the level of discussion include sensitive or classified information.

The final step in the SME interview process was to determine what selected cognitive attributes were needed to successfully perform a given task and/or task element. To do this, a seven-point Likert-like scale was used in conjunction with a task-by-attribute matrix that was developed based on the results of the SME interview process. The results are shown in table E-1. Table E-2 contains the duration of subtasks and performance criteria for the steps of the Evaluate the Threat task.

During interaction with the SMEs at Fort Huachuca, an additional (tenth) attribute, along with a description, was identified as critical by the SMEs:

Perseverance: An ability to want to coax the best possible answer out of a situation and act on it in an appropriately timely manner knowing the situation and associated repercussions.

The need for perseverance was a consistent theme across the SMEs interviewed for this effort, and as such, we included the attribute in the subsequent analyses for the project. However, it is interesting to note that this particular attribute was not highlighted in the literature review conducted to develop the attribute list. Multiple potential reasons for the disconnection between the literature and SME opinions are plausible. First, much of the literature we reviewed was focused on the initial analysis activities, that is, the literature sought to describe what was required to collect, filter, and transform data into information to create a product. Because the literature focused on the initial analysis efforts, the resilience and persistence that characterizes perseverance would likely not come into play in the initial analytic efforts. Second, because much of the literature is concerned with intelligence product generation as a measure of performance, it is reasonable to believe that perseverance is not as important in creating initial products but would increase in importance with a need to revise or update products to achieve a greater level of understanding of the situation being analyzed. Regardless, it is clear that expert analysts believe that to be effective at the job of an MOS 35F, a sort of resilience or persistence of effort is required, and this attribute was included in our task rating and modeling activities.

In addition to perseverance, through the discussions with the SMEs, two additional characteristics were identified as being consistent with an IA who possesses desirable performance traits. The SMEs consistently cited a need for the ability to organize information and to be an effective collaborator. Descriptions of these were formed and are as follows:

- Organization of Information: An ability to come up with a system or method to save and store information for retrieval and communication.
- Collaboration: An ability and willingness to share and debate/discuss ideas with others.

Based on SME input, it is apparent that these abilities are vital elements for success as a 35F all-source analyst. However, for several reasons, within the current effort we elected not to include them in efforts to quantify the relationship between analyst attributes and performance. First, for collaboration, since this effort was focused on individual activities associated with analysis, the ability to work with others was considered outside the bounds of the initially established investigation. However, it is important to note that the trend towards team-based analysis for intelligence professionals may increase the importance of collaboration for successful product generation. As such, we recommend that this attribute and the others identified for this effort be reexamined as part of an effort to understand the impact of team-based analysis. In regard to organization of information, the team suspects that this ability is likely a higher-level construct that requires the analyst to have a number of lower-level attributes (e.g., critical thinking, deductive reasoning, etc.) to effectively perform.

Figure 1 shows the form used to note the ratings of the various task demands for each of the subtasks of the Evaluate the Threat task. Table E-2 reports the ratings that the SMEs gave to the attributes/abilities relevant to the subtasks of the Evaluate the Threat task.

Task #	Activity (or Sub-Task)	Ability or Task Demand									
	Needed to perform the activity: **1 = a minimum amount is needed** **4 = a moderate amount is needed** **7 = a great amount is needed**	1 Memorization	2 Selective Attention	3 Time Sharing	4 Deductive Reasoning	5 Inductive Reasoning	6 Problem Sensitivity	7 Flexibility of Closure	8 Fluency of Ideas	9 Originality	10 Perseverance
1	Depict the composition and array of enemy network in an AO, AI, and AOI based on operational variables (PMESII-PT ASCOPE) and TTPs.										
2	Develop RFIs										
3	Update COP with current enemy composition										
4	Develop HVI/HVT/HPTs										
5	Verify gaps in intelligence holdings										
6	Identify relevant databases										
7	Verify METT-TC effects on threat forces										
8	Draft threat assessments to develop realistic Threat models										
9	Develop enemy OB/structure										
10	Analyze intelligence holding IOT identify existing or emerging enemy TTPs										
11	Develop initial ECOAs based upon										
12	Develop threat capabilities statement in Full Spectrum is focused on units										

Figure 1. SME task demand rating form.

Table 4 presents the final list of critical aptitudes/abilities needed by the 35F all-source analyst and criticality ratings by SMEs. SMEs 1, 2, and 3 graded all the abilities and used a grading scale of A, B, C, D, and F, with A being the best; SME 4 used a scale of 1 to 7, with 1 being the highest level of importance, and the abilities that were not rated still being considered critical but not one of the top seven abilities.

Based on the interview results and associated discussions with the SMEs, the following results were obtained:

- The nine identified cognitive attributes and their associated definitions (see table 4, attributes 1–9) were confirmed by the SMEs to be relevant for 35F analysts; however, the SMEs added one additional attribute referred to as "Perseverance" to the list (see attribute no. 10). The SMEs subsequently added two more abilities/skills to the list of critical attributes for the 35F all-source analyst, Organization of Information and Collaboration, resulting in the list of 12 attributes shown in table 4.
- It was decided that the task of primary interest for our model should be "Evaluate the Threat" as it met the preestablished characteristics of requiring cognitive-relevant components of analysis, reasoning, and decision making and was identified by SMEs as one of the most critical 35F tasks.

- The task element characteristics and the attribute ratings for selected task elements were obtained and translated into appropriate coding language for use in the exploratory model.

Table 4. Final list of critical aptitudes/abilities needed by the 35F all-source analyst and criticality ratings by SMEs.

	Ability	Description	SME 1	SME 2	SME 3	SME 4
1	Memorization	An ability to remember information, such as words, numbers, pictures, and procedures.	B	B	A	3
2	Selective attention	An ability to concentrate on a task over a period of time without being distracted.	D	A	D	—
3	Time-sharing	An ability to shift back and forth between activities or sources of information, such as speech, sounds, touch, or other sources.	C	B	C	7
4	Deductive reasoning	An ability to apply general rules to specific problems to produce answers that make sense.	A	A	A	1
5	Inductive reasoning	An ability to combine pieces of information to form general rules or conclusions (includes finding a relationship among seemingly unrelated events).	A	A	A	2
6	Problem sensitivity	An ability to tell when something is wrong or is likely to go wrong. It does not involve solving the problem, only recognizing that there is a problem.	B	B	B	5
7	Flexibility of closure	An ability to identify or detect a known pattern (e.g., a figure, object, word, or sound) that is hidden in other distracting material.	B	A	B	—
8	Fluency of ideas	An ability to come up with a number of ideas about a given topic (the number of ideas is important, not their quality, correctness or creativity).	D	B	B	4
9	Originality	An ability to come up with unusual or clever ideas about a given topic or situation, or to develop creative ways to solve a problem.	C	C	C	—
10	Perseverance	An ability to want to coax the best possible answer out of a situation and act on it in an appropriately timely manner knowing the situation and associated repercussions.	A	C	D	6
11	Organization of information	An ability to come up with a system or method to save and store information for retrieval and communication.	C	B	B	—
12	Collaboration	An ability and willingness to share and debate/discuss ideas with others.	A	A	B	—

2.5 IMPRINT Modeling

IMPRINT* is a simulation and modeling tool that provides a means to estimate Manpower, Personnel, and Training (MPT) and Human Factors Engineering requirements and to identify constraints for new weapon systems early in the acquisition process. The IMPRINT tool grew out of common U.S. Air Force, Navy, and Army MPT concerns identified in the mid-1970s. It is government-owned software and consists of a set of automated aids to assist analysts in

*http://www.arl.army.mil/www/default.cfm?page=445 (accessed March 2012).

conducting human performance analyses. IMPRINT has been available as a government product free of charge since the mid-1990s to U.S. government agencies, U.S. private industry with U.S. government contract, and U.S. colleges and universities working in Human System Integration. It is supported by commercial-quality user documentation, a training course, and a technical support organization. Upgrades and enhancements to IMPRINT have been driven by user requirements, human modeling research, and changes in the state of the art in computer simulation. IMPRINT provides a powerful and flexible environment in which to develop human performance models and has unique capabilities for assessing the impact of stressors (e.g., noise, heat, sleep deprivation, protective gear) on performance.

One of the most powerful and unique capabilities in IMPRINT is the method through which Soldier characteristics and environmental stressors can be used to impact task performance. This is achieved through an embedded simulation engine, based upon the commercial Micro Saint Sharp product[*] and supplemented by human performance algorithms. The application includes a graphical user interface (GUI) shell that elicits information from the user needed to assess human performance issues associated with the operations and maintenance tasks of a weapon system. The simulation and analysis capabilities in IMPRINT along with the embedded data and GUI have been demonstrated to enable human factors professionals to impact system design and acquisition decisions based on early estimation of Soldiers' abilities to operate, maintain, and support the system.

Following is a description of the tasks modeled, how data to support and populate it were collected, and the scenarios against which the model was run (i.e., Stability and Support Operations [SSO], Full-Spectrum Operations [FSO]).

For this effort, the activities to be modeled were those involved with a level-20 IA (i.e., a 35F) performing the "Evaluate the Threat" activity. This activity, while agreed upon as representative, is only 1 of 72 "activities" an IA may perform and only 1 of 18 that a level-20 IA may be called upon to perform (figure 2).

Each task node consists of a single task (indicated by an oval) or a collection of subtasks (indicated by a rectangle). Within each rectangle is a subnetwork that consists of tasks and possibly more sublevels of subnetworks. For example, the rectangle depicting the task of Evaluate the Threat for a skill level-20 analyst (task 301-35F-2253) is shown in figure 3. (The tasks conducted by an IA with a skill level of 20, according to the PS&M, are listed in table 5.) This subnetwork comprises the tasks that constitute what a level-20 analyst should be able to perform. The ratings that the SMEs gave to the attributes/abilities relevant to the subtasks of this activity are given in table D-1.

Each task node consists of arithmetic logic and algorithms that are used to model attributes of interest. For example, each node encapsulates an algorithmic expression of task time that

[*]http://www.alionscience.com/Technologies/Simulation-and-Visualization/Micro-Saint-Sharp (accessed March 2012).

represents the duration. Further, upon executing the task, logical expressions and equations can be evaluated and calculated, respectively, to model interactions between tasks and between tasks and the operational environment. For the purposes of this effort, each task calculated the amount of time in hours per 12-h shift that the analyst would perform this subtask. Software code to implement this task time is written in the programming language C# (pronounced C sharp), an example of which is shown in figure 4.

Similarly, upon the execution of each task, the code within the task is activated. The code shown in figure 5 is used to calculate a "score" for each cognitive ability (or task demand) and is the summation across all the subtasks of the task time duration (in units of hours per 12-h shift) and a rating offset. The rating offset is a compilation of the ratings given by the SMEs to each cognitive ability.

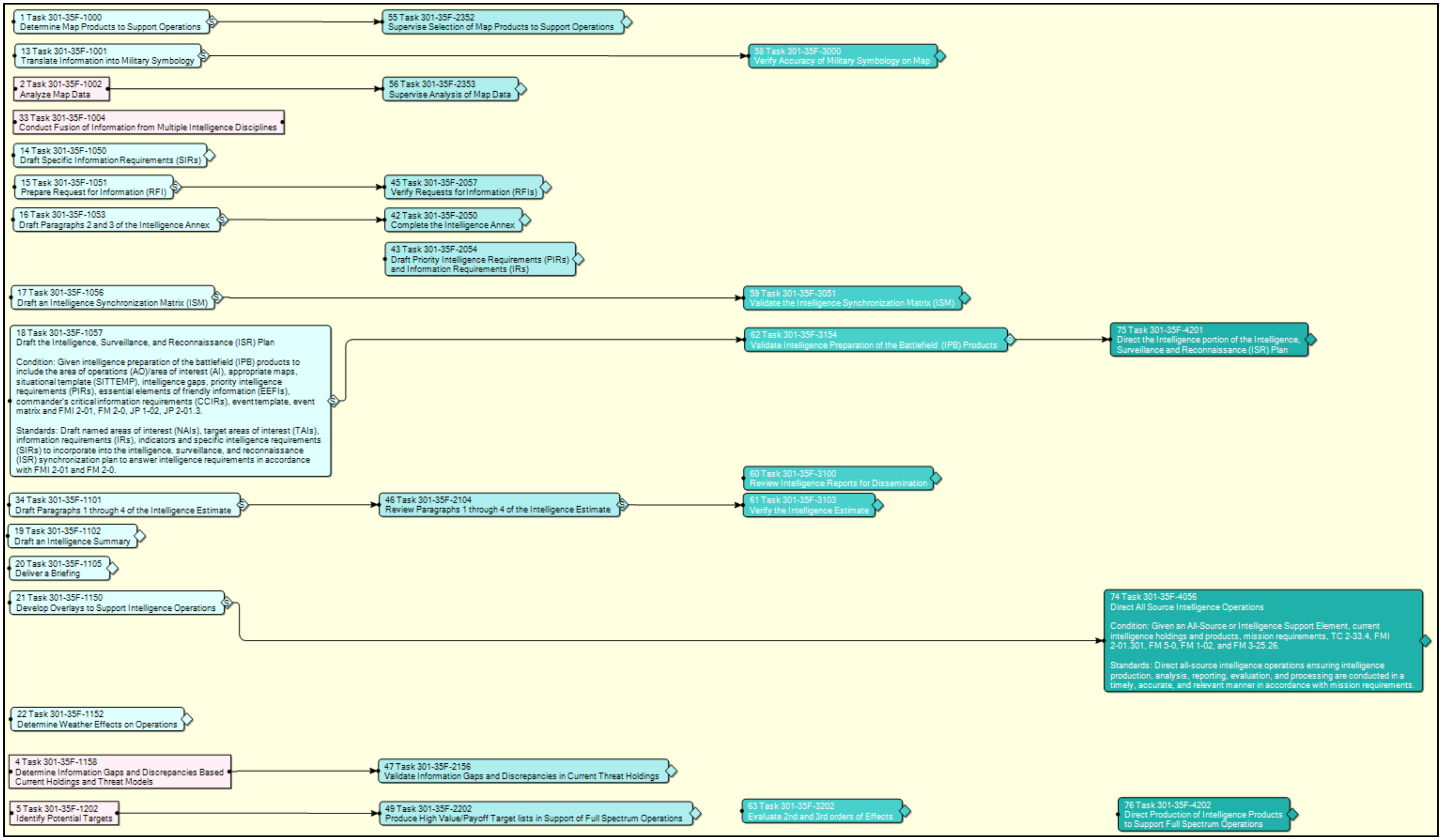

Figure 2. Task network diagram of the tasks performed by a 35F.

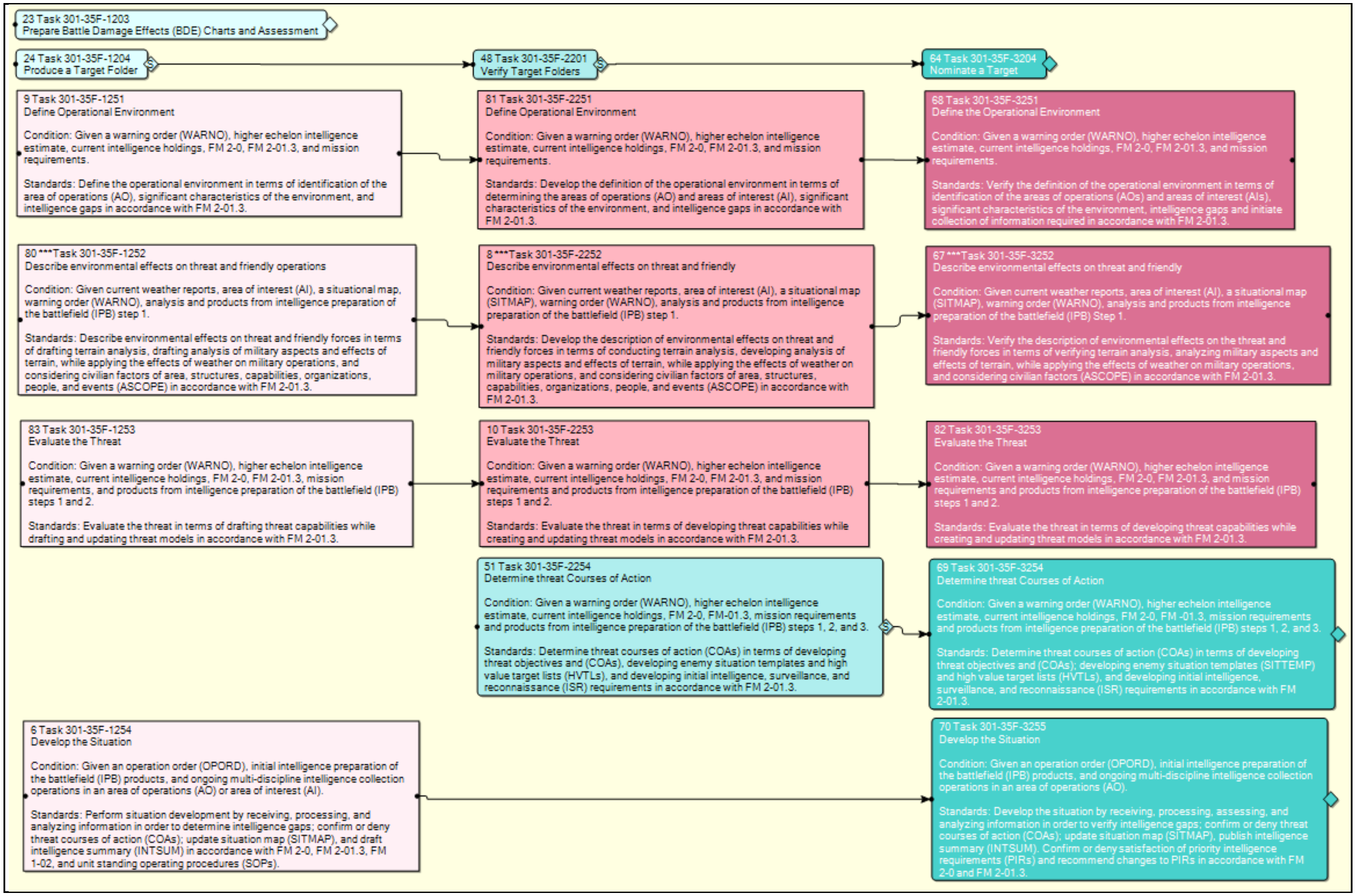

Figure 2. Task network diagram of the tasks performed by a 35F (continued).

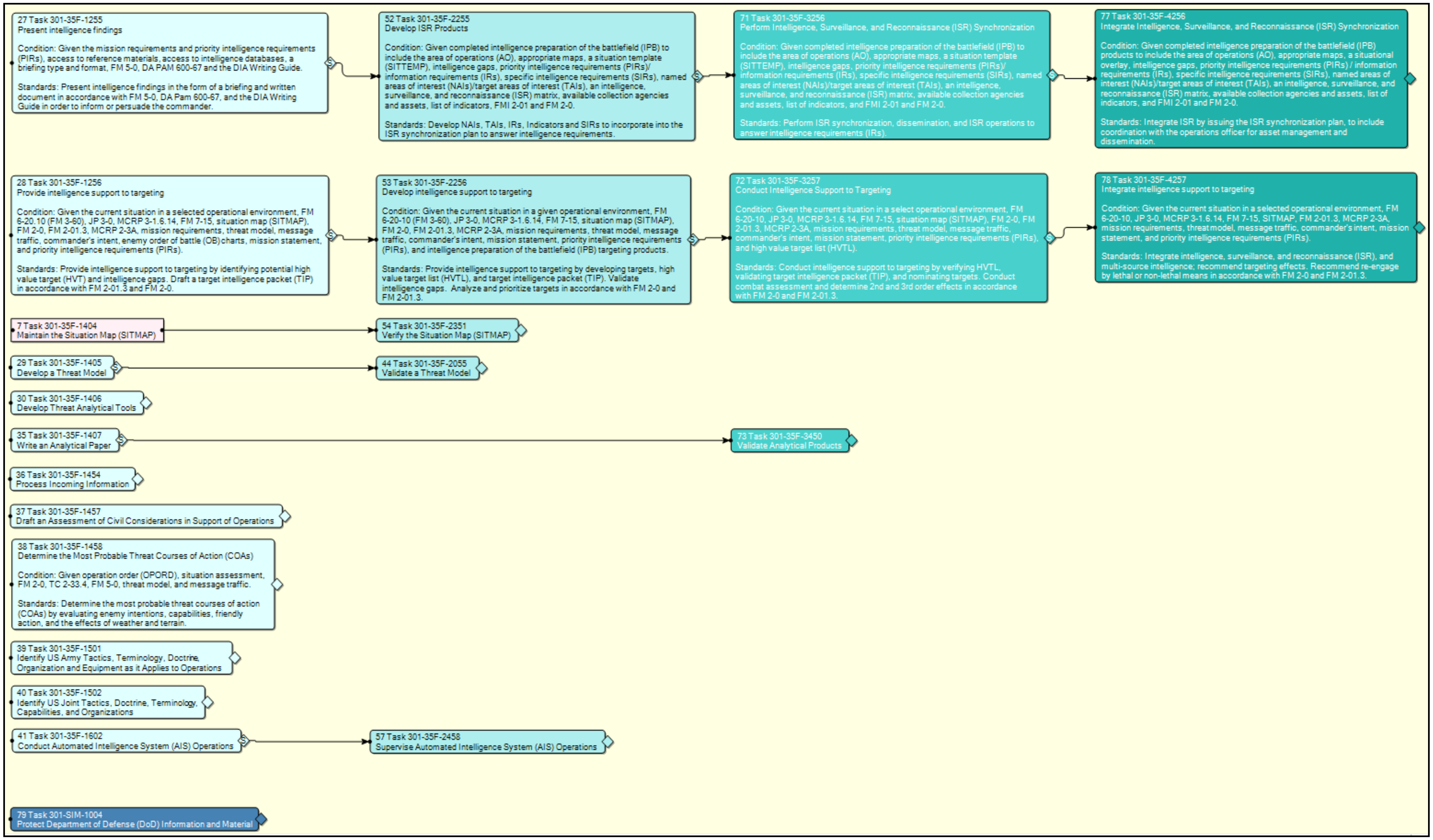

Figure 2. Task network diagram of the tasks performed by a 35F (continued).

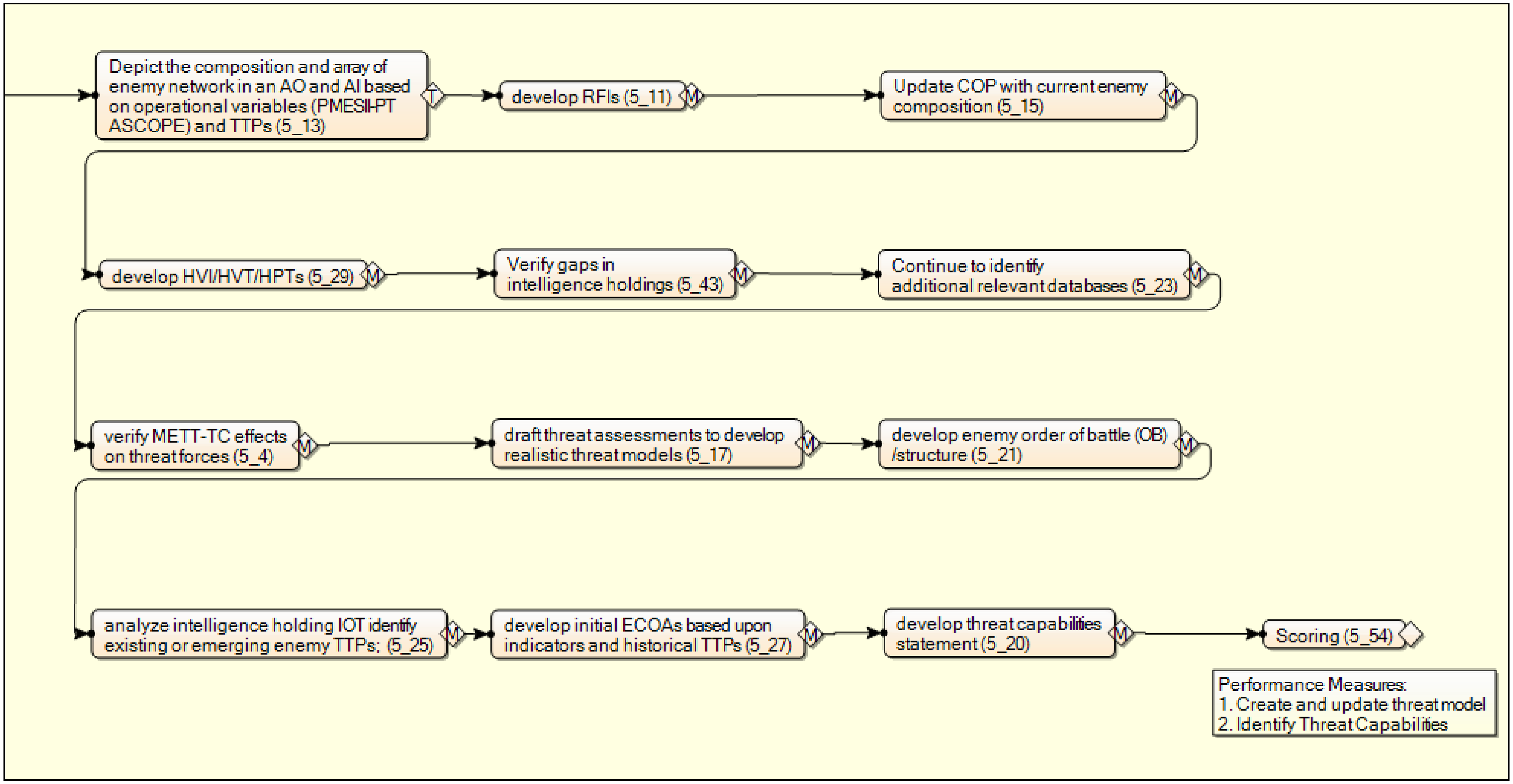

Figure 3. Task network diagram of Evaluate the Threat, skill level-20 subtasks.

Table 5. Level-20 subtasks of Evaluate the Threat.

Task No.	Activity (or Subtask)
1	Depict the composition and array of enemy network in an area of operation (AO) and area of interest (AI or AOI) based on operational variables (PMESII-PT ASCOPE) and tactics, techniques, and procedures (TTPs).
2	Develop requests for information (RFIs).
3	Update the common operational picture (COP) with current enemy composition.
4	Develop high-value individual (HVI)/high-value target (HVT)/high-payoff targets (HPTs).
5	Verify gaps in intelligence holdings.
6	Identify relevant databases.
7	Verify METT-TC effects on threat forces.
8	Draft threat assessments to develop realistic threat models.
9	Develop enemy order of battle (OB)/structure.
10	Analyze intelligence holding; identify existing or emerging enemy TTPs.
11	Develop initial enemy courses of action (ECOAs) based upon indicators and historical TTPs.
12	Develop threat capabilities statement.

```
// task duration is in hrs/12-hr shift
// In a 12-hr shift, Indicate the # of hours spent doing this
double taskDuration = 0.0;
double numShifts = 1.0;

if (IA[Entity.Tag].TypeOfOperation == OPERATION_FSO)
{
       // 1-2 hrs, every 12-24 hrs (every 1 to 2 12-hr shifts)
       taskDuration = Distributions.Rectangular(1.5, 1.0);
       numShifts = Distributions.Rectangular(1.5, 1.0);
}
else if (IA[Entity.Tag].TypeOfOperation == OPERATION_SSO)
{
       // 10-15 min, ongoing (0 to 4 times per 12-hr shift)
       taskDuration = Distributions.Rectangular(15.0, 10.0) / 60.0;
       numShifts = Distributions.Rectangular(2.0, 0.0);
}
else
       return 0.0;

return taskDuration / numShifts;
```

Figure 4. Sample model code for task time calculation.

```
// Score = time duration in hours * cognitive ability rating
// given by the SMEs to this ability for this task.
// Collect a scoring for each of the following:
//   skill level
//   type of operation
//   cognitive ability

double normalizedTaskRating;
double ratingOffset = 0.0;
for (int thisAbility=0; thisAbility<NumAbilities; thisAbility++)
{
      // What is the difference between a "good" analyst and this
guy?
      normalizedTaskRating =
(TaskRatingOfGoodAnalyst[thisAbility] -
1.0) / (double)(7 - 1);
      ratingOffset = normalizedTaskRating -
IA[Entity.Tag].AbilityRating[thisAbility];

      IA[Entity.Tag].ETT_Score[thisAbility] += (Entity.Duration *
ratingOffset);
//    Model.PrintOutput("Entity " + Entity.Tag
//          + " this Ability " + thisAbility
//          + " normalizedTaskRating " + normalizedTaskRating
//          + " IA[Entity.Tag].AbilityRating[thisAbility] " +
IA[Entity.Tag].AbilityRating[thisAbility]
//          + " Entity.Duration " + Entity.Duration);
}
```

Figure 5. Sample model code for attribute ratings.

3. Results

3.1 Cognitive Attribute Effects on Performance

The purpose of intelligence analysis is to create intelligence information from data acquired from a variety of sources. A successful analyst produces an intelligence product that conveys intelligence information and meets the consumer's needs. Performing the IA job requires appropriate skills and abilities, knowledge, and personal characteristics that are associated with rigorous intelligence analysis and production. The ability to communicate, cooperate, and think critically, coupled with the skills that ensure technical competency, is a requirement for intelligence work. Knowledge of the issues and their background provides both content and context for analysis. "Analysts who are motivated to succeed, to know targets, and to share that knowledge ensure that consumers receive intelligence of the highest caliber" (Swenson, 2003).

The goal of this effort was to identify the characteristics that an all-source analyst must possess to succeed in these activities. The work conducted to achieve this goal produced a variety of outputs that have value to the Army intelligence community and the intelligence community at large. Specifically, the standardized test available for measuring the attributes needed for a successful analyst provides a way for improving the selection and assignment of individuals to the IA job family. Additionally, the quantitative relationships between analyst attributes and performance established through the meta-analytic activities can aid in prioritizing the extensive set of required attributes based on their likely contributions to overall performance, while the gaps identified in the literature search suggest paths forward for rounding out the theory-driven investigations needed to develop a more comprehensive approach to selection, assignment, and training of intelligence professionals. Finally, the skill usage information generated from the task network modeling efforts, in conjunction with the test information and performance relationships, can point to high-priority attributes that are likely to be utilized most often across intelligence analysis mission types and as such have more significant impacts on overall performance.

The following sections summarize the outputs of the investigations conducted under this effort, and the report concludes with a set of recommendations that are intended to provide a basis for continued investigation and actions that will improve the performance of IAs for the U.S. Army.

3.1.1 Standardized Tests

Appendix C provides a summary of the tests identified from the literature and from the Mental Measurement Yearbook (Spies et al., 2010) that measure attributes considered by researchers and SMEs to be critical to IA performance. Each test identified could improve the ability to select/assign personnel to an intelligence analysis MOS by adding a predictor to the overall assessment battery used for MOS assignment. The assessments vary in the resource demands for administration, but as noted in the recommendations, implementation of targeted attribute tests from those identified here may offer some near-term improvements to IA performance.

3.1.2 Performance Relationships

Appendix D provides a summary of performance effects compiled from the literature. It contains descriptions of effects matrices that target one or more of the cognitive abilities. From this information, the following high-level results emerge:

- Critical thinking was found to impact the broadest range of task demand groups of the 13 measureable attributes reviewed for this effort.
- Flexibility of closure appeared in more quantitative studies than any other attribute, and as such, its impact on performance in IA-related tasks is well established.
- Tasks requiring deductive reasoning, inductive reasoning, and flexibility of closure are frequently used in the experimental literature; the impact of personnel attributes on those

tasks is well established and may be a useful starting point in improving analyst task performance.

- Although only found in one study, Motivation/Perseverance appears to have a strong performance impact on tasks requiring collaboration.

3.1.3 Gaps/Missing Pieces in the Literature

The database searches that attempted to identify empirical research linking attribute levels to task performance, based on the tests used to measure attribute levels, identified tens of thousands of abstracts with potential data linking personnel attributes to task performance. Time and resource limitations on the current effort only allowed for inclusion of several hundred of these studies as part of the current meta-analysis effort. Consequently, further exhaustive data collection could reveal that some of the gaps identified in the current matrix are the result of sampling rather than a true gap in the literature. Additionally, further work would be needed to increase the certainty around the estimated effects noted here. However, based on this cursory review, a few likely gaps can be hypothesized based on the relatively low numbers of studies included in our initial sampling. For instance, our results found only one study with quantitative impacts of induction on task performance. Likewise, only one study quantifying the impacts of motivation /perseverance on task performance was identified. These attributes, along with some specific attribute-to-task demand pairings, may bear further investigation in the literature to establish them as true gaps in knowledge and to determine the likely payoff in terms of improved predictive ability that could be gained if the gaps were closed.

3.2 Modeling Results: Skill Usage Profiles Across Mission Types

Model results were calculated for FSO (table 6) and SSO (table 6). Based on information gathered from IA SMEs, the amount of time spent on each skill level-20 subtask of the Evaluate the Threat task was estimated on a yearly basis (table E-2). These hours were then summed for each of the 10 task demands for each rating level. Again, the rating levels were obtained from SME interviews.

When looking at the amount of time the analyst will spend exercising the attributes required for task performance across both FSO and SSO, we see from the model that each attribute is required for approximately equal amounts of time. This finding reinforces the message that the SMEs communicated during data collection—that all the identified attributes contribute to successful job performance for the all-source analyst. However, when the time spent performing specific tasks is examined in combination with the attribute criticality ratings provided by the SMEs, a few attributes appear to be required more often at critical levels. For FSO, the attributes of time sharing, problem sensitivity, and flexibility of closure have more time of utilization on tasks where those attributes are needed most for task completion. Similarly, in SSO, time sharing, problem sensitivity, and motivation/perseverance are used for the longest duration on tasks where those attributes are in high demand.

Table 6. Hours per year spent utilizing specific abilities for a level-20 IA while conducting Evaluate the Threat during full-spectrum operations.

Rating	Memorization	Selective Attention	Time-sharing	Deductive Reasoning	Inductive Reasoning	Problem Sensitivity	Flexibility of Closure	Fluency of Ideas	Creativity / Originality	Motivation / Perseverance
1								13	13	
2							13			
3	13							836		
3 1/2										13
4		35							1,166	
4 1/3										
4 1/2			35						35	
4 2/3										
5	114	814	78	8		56		91	92	
5 1/3										
5 1/2				178				365	36	78
5 3/4								36		
6	801	460	13	836	122	78	514	79		78
6 1/4				1	814					801
6 1/3										
6 1/2		37			365	365				464
6 2/3										
6 3/4					87					
7	186	91	1,389		91	925	893			81

An additional output from the modeling effort that can help focus future actions for improving overall analyst performance is results indicating the amount of time an analyst spends on specific tasks over the course of the year. When the Evaluate the Threat tasks are simulated for over a year of performance, the model can point to high driver tasks that can be expected to have significant impacts on mission performance. For each high driver task, a set of required cognitive attributes is identified that, along with the results in tables 6 and 7, can help focus future action on attributes that are likely to have the most impact on overall performance.

On the whole, the model outputs suggest that the IA should possess the diverse set of characteristics suggested by the literature search and confirmed by the SMEs. Additionally, the model results taken in conjunction with the SME ratings may indicate that time sharing and problem sensitivity could be considered more important for the analyst, while attributes such as creativity, originality, and fluency of ideas—while frequently exercised in performing IA tasks—are required to a lesser degree for mission performance than the other attributes identified.

Table 7. Hours per year spent utilizing specific abilities for a level-20 IA while evaluating the threat during stability and support operations.

Rating	Memorization	Selective Attention	Time-sharing	Deductive Reasoning	Inductive Reasoning	Problem Sensitivity	Flexibility of Closure	Fluency of Ideas	Creativity / Originality	Motivation / Perseverance
1								13	13	
2							13			
3	13							126		
3 1/2										13
4		35							91	
4 1/3		78				91				
4 1/2			35						35	
4 2/3		104		91					78	
5	2,268	104	78	8		56		195	351	
5 1/3					35				104	
5 1/2				299					2,190	78
5 3/4				260				2,190		
6	195	476	13	230	2,276	78	2,303	598		78
6 1/4				260	104					91
6 1/3					260	104			260	
6 1/2		2,450			104					463
6 2/3				2,190	260					
6 3/4					208					
7	567	91	3,213		91	3,009	547			2,615

4. Recommendations

The extensive literature review and modeling effort that were performed revealed a great deal about the requirements for effective intelligence analysis. A consensus from the literature exists that the duties of the IA are diverse and complex, requiring a variety of core functional competencies for successful completion. Complex relationships exist among these core competencies required for effective analysis, and more specifically, among the cognitive attributes. These complex relationships are not well described or understood in the literature. While it is apparent that many of the cognitive attributes that are described as characteristic of an effective analyst, both in the literature and confirmed as part of this effort, are conceptually related to one another, the impact that the individual attributes have on performance and the relationships between them is much less clear or well understood. This fact made quantifying the impact of varying attribute levels on mission performance a significant challenge. However, the human performance model built for this effort highlights the attributes that are important over time in an analyst's mission and, as such, is useful in directing further investigation into the relationships among attributes and between attributes and ultimately analyst performance. The literature review, SME interactions, and model development and analysis efforts have pointed to a number of recommended actions that could be undertaken to improve IA performance either through selection and assignment, training, or capability development.

4.1 Immediate Term

Consider implementing a test for Flexibility of Closure as part of the analyst selection and assignment process.

Flexibility of Closure, an important measureable ability that seems to exhibit strong positive relationships with IA-like tasks, is defined as follows:

- The ability to identify or detect a known pattern defined as a figure, object, word, or sound that is hidden in other distracting material.
- The ability to demonstrate selective attention to a specified set of elements when presented within various settings (the larger the number of settings from which the desired set of elements can be selected, the higher the level of flexibility of closure).
- The ability to dissemble information from a distracting field.

Flexibility of Closure is something readily measureable with closure-specific tests or closure indices within larger test batteries. It would be a worthwhile pursuit to test current IAs on Flexibility of Closure ability and assess whether scores demonstrate potential as a descriptive discriminator between IA that have "the right stuff" and those that do not. Alternately, some researchers assert that this ability can be improved through training. Effort should be undertaken to determine if the addition of training materials specifically geared to improving this attribute would support improved analyst performance.

Determine if existing measures of critical thinking and reasoning skills discriminate between high- and low-performing analysts and consider introducing such an assessment to existing selection batteries.

Critical thinking and reasoning skills also seem to exhibit strong positive relationships with IA-like tasks. In particular, the model results indicate that analysts spend approximately one-third of their time developing HVIs, a task that requires deductive reasoning and problem sensitivity. The meta-analysis results indicate that measures of critical thinking are strong predictors of performance on these types of tasks. Because of the amount of time spent on this task and the ability of critical thinking measures to predict performance, selecting for improved critical thinking skills could improve performance on high-demand tasks like developing HVIs. An immediate benefit could be realized through adding a validated test of critical thinking skills to the selection and assignment battery for all source analysts. A first step in this process would be to test current analysts on critical thinking and reasoning skills and compare those results to performance evaluations to determine whether scores on the critical thinking test demonstrate potential as a descriptive discriminator between high- and low-performing analysts.

Evaluate the potential for improving deductive reasoning in existing analysts as a means for targeted performance improvement.

The model results suggest that two of the activities analysts spend the most time performing, Develop HVI and Develop Enemy Order of Battle, both require moderate to high levels of deductive reasoning. Training to improve deductive reasoning has long been addressed in the research literature (see Sleeman, 1975, for example), and the capability to improve deductive reasoning ability may be easily available. Because of the frequency of use and relative importance of this ability, a near-term investment in efforts to improve current analyst deductive reasoning ability may provide a reasonable return on investment.

Further explore the role of strategy development; executive IP functions may be warranted.

We found no JCAT attributes that reflected what we refer to as executive IP functioning related to strategy development and use that are often associated with metacognitive processes; therefore, we believe that the exploratory model provided for this project may be expanded to include these other potentially useful cognitive constructs, assuming that future empirical results can be used to match these attributes to specific IA tasks.

Identify specific quantifiable performance metrics for evaluating analyst performance on critical analysis tasks.

The literature review found that the lack of available quantitative measures of effective performance on IA tasks is a frequently cited challenge in efforts to understand and improve analyst performance. This was confirmed in the current effort through our interactions with analyst SMEs in our attempts to develop quantitative task–level performance criteria for use in developing algorithms to characterize the relationship between attribute levels and analyst performance. Identifying and describing analysis products with measures of performance and effectiveness that can be quantified could provide a valuable step in understanding how to predict which individuals will perform well as IAs.

4.2 Mid-Term

Further explore attributes of successful analysts who increasingly function in a team-based environment.

With increasing amounts of information available and the ability to share that information across organizational boundaries (e.g., between units, military branches, and non-military agencies), there is a trend toward increased team-based analysis activity for intelligence-related data. This effort found that collaboration is an important characteristic for analysts in this environment. However, beyond collaboration requirements, team-based analysis may require a different set of attributes altogether, and understanding the differences between the attributes required for individual analytic activity vs. team-based activities may be important. Additionally, questions such as, Can one team member with above-average abilities in a specific area compensate for the lack of that ability in another team member, are likely to become more relevant as analysis continues to develop into a team-level activity.

More broadly examine the range of ability tests that can discriminate good from bad analysts above and beyond the current Armed Services Vocational Aptitude Battery (ASVAB) test composites that are used for selection into the specialization.

As outlined in appendix C of this report, a number of validated and generally available instruments exist for measuring the cognitive attributes required for successful IAs. Many of these assessments may improve the Army's ability to select individuals into an intelligence MOS. In order to understand the potential improvements in predictive ability that could be provided by a subset of these assessments, a study could be conducted to evaluate the added predictive power that selected tests may provide above and beyond what is currently provided by the ASVAB.

Conduct controlled experiments and testing to identify the breadth of ability tests that prove useful for discriminating good from bad analysts and predict success (and therefore informing selection) across missions.

Because the job of an all-source analyst is complex and requires a variety of higher-level cognitive abilities, the Army would benefit from the conduct of a set of controlled experiments and testing efforts that could begin to isolate the specific attributes and associated available measures that discriminate successful from unsuccessful analysts.

Explore the use of nonability-based measures, such as biodata, for analyst selection and assignment.

A common theme in the literature and in our interviews with analyst SMEs was that the amount and diversity of analyst experience is a good predictor of the quality of analysis that an analyst will produce and the success he or she will likely have in the field. As such, an effort to describe and categorize the types of experiences that are of value to the analyst could lead to the development of a life history measure that would identify the candidate analyst who could bring to the job a set of experiences that could predispose him or her to success in the analysis domain.

4.3 Far Term

Examine the trainability of important abilities for successful IAs.

Much of the focus of the current effort was on identifying key analyst attributes that could be quantified through existing measures and understanding the impact those attributes have on analyst performance. The results of the effort point to a number of key analyst attributes that contribute to effective performance. The ability to measure the attribute is a necessary precursor for both including a measure of the attribute as part of the analyst selection criteria and also for potentially introducing training to the analyst program of instruction aimed specifically at improving some of these attributes. The Intelligence School may benefit from an effort to understand which of the critical attributes can be trained, so that training materials or courses can be developed (or purchased) to improve analyst proficiency on specific attribute-related activities.

Investigate research areas involving neural (EEG) mapping that may help link higher-level cognitive performance (e.g., reasoning, strategy use, decision making, etc.) to lower-level IP activities that support and enhance the higher-level cognitive performance outcomes.

The area of neural (EEG) mapping has made significant progress over the past 10 years and provides the potential for establishing direct links between overt performance in the way of strategy use, reasoning, and decision making, and activities associated with how humans store and process information.

Perform a componential analysis of critical IA tasks to identify the individual abilities and aptitudes that are correlated with (predict) performance on specific IA tasks and subtasks.

A componential analysis would identify the specific independent aptitudes and skills that are predictive of "good" IA task performance, and the weights (or importance) of each aptitude or skill to overall performance. This would help to develop a profile of the "exceptional" analysts and provide ways to "trade-off" skills to identify the potentially "best" analyst given a pool of candidates.

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Appendix A. Bibliography of Research Reviewed

This appendix contains the full set of literature we reviewed as part of this project effort. The list contains references on the intelligence analysis process, relevant performance metrics for analysis, the attributes required to accomplish the analysis process, and general references to the cognitive attributes evaluated in this project. The purpose of this appendix is to provide a comprehensive resource list for the areas the research team investigated and to catalogue those resources that, although influential to the project as a whole, were not directly cited in the final report.

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Appendix B. Summary of Initial Literature Review

This appendix appears in its original form, without editorial change.

B.1 Sternberg Triarchic Theory/Componential Analysis References

Overall Summary: Sternberg's theory of intelligence is focused on identifying and measuring how individuals process information. His theory states that an individual's environment or world context is critical for identifying and understanding intelligent behavior and that one's knowledge about their own (strategic) thinking processes (i.e., metacognition) as well as their ability to evaluate and modify their cognitive strategies (i.e., executive control processes) are key elements of intelligence.

The theory posits a subtheory of human intelligence based on component constructs that act at varying levels: (a) metacomponents (higher order planning, monitoring, evaluating, etc.), (b) performance (executing problem-solving strategy), (c) acquisition (learning new strategy), (d) retention (retrieving stored knowledge), and (e) transfer (applying learned strategy to other situations). By analyzing these component constructs via "componential analysis" techniques, one can presumably isolate their impact on performance, as well as develop training that can improve performance.

Sternberg has used cognitive constructs to decompose selected psychometric tests as a way to better isolate, understand and measure the specific information-processing elements that influence test performance.

One interesting aspect to Sternberg's theory is that as an individual's metacognitive processes become more effective and efficient (i.e., automated), then mental capacity may be freed up for other important information-processing/strategic thinking activities (e.g., situational awareness, identifying viable alternative strategies/options, creativity, etc.). While this view is based on the study team's understanding of Sternberg's theory and thus has yet to be demonstrated empirically, it may help to provide a future area of research that could lead to improved information-processing capability of IA personnel.

Bettman, J.R., Johnson, E.J., and Payne, J.W. (1990). A componential analysis of cognitive effort in choice. *Organizational Behavior and Human Decision Processes*, 45 (1), 111-139.

Summary: Describes use of elementary information processes (EIPs) that are required to execute a given decision strategy. These component processes form the basis of a model that can be used to predict mental effort needed to execute a decision strategy. Authors report that models developed using this approach were good predictors of task-specific response times and subjective reporting of task-related effort.

Sternberg, R.J. (1985). *Beyond IQ: A triarchic theory of intelligence*. Cambridge University Press, New York, NY.

Summary: Describes Sternberg's Triarchic Theory as having 3 sub-theories: Contextual, experiential and componential. Contextual sub-theory relates intelligence to what is going on in the world around the individual and answers the "for whom and where" behaviors are intelligent. Experiential sub-theory relates intelligence to both the external and internal worlds of the individual and answers the "when" behaviors are intelligent. The Componential sub-theory relates intelligence to the internal world of the individual and answers the "how" behaviors are intelligent. This last area describes the mental mechanisms that underlie intelligent behavior.

Sternberg, R.J. (1981). Testing and cognitive psychology. *American Psychologist*, 36 (10), 1181-1189.

Summary: Describes four major approaches to understanding mental abilities: (1) Cognitive correlates, (2) cognitive components, (3) cognitive training, and (4) cognitive contents. Taken together these approaches help one understand performance differences on psychometric tests due to the underlying mental processes required to perform a given test.

B.2 Neural Activity (EEG) Tracking References

Overall Summary: The ability to measure neurological functioning and relate it to specific cognitive functioning has grown steadily over the past 10–15 years. Of direct importance to this project are studies that show a relationship between specific neurological activity and short-term (working) memory as well as other (strategic) functioning that can used to predict performance on complex tasks. Another intriguing finding (see Jaeggi et. al., 2008) is the potential for improving cognitive processes related to fluid intelligence that can transfer to other, unrelated tasks.

Gevins, A., Smith, M.E., McEvoy, L.K., and Yu, D. (1997). High-resolution EEG mapping of cortical activation related to working memory: Effects of task difficulty, type processing and practice. *Cerebral Cortex*, 7 (4), 374-385

Summary: Presents evidence of brain activity associated with working memory tasks and that as practice increased there was a reduction in this activity. In addition, some support was found for identification of a "coherent functional network" of cortical activity when subjects were presented with more difficult memory tasks.

Gevins, A. and Smith, M.E. (2000). Neurophysiological measures of working memory and individual differences in cognitive ability and cognitive style. Cerbral Cortex, 10 (9), 829-839.

Summary: Describes between-subject differences in brain activity related to the capacity to deliberately control attention in order to manipulate information in working memory. Results indicate that high-ability subjects developed strategies that made greater use of parietal brain regions versus low-ability subjects more exclusive use of frontal regions. Results reflect ability to show brain-related activity associated with differing cognitive ability and style.

Jaeggi, S.M., Buschkuehl, M. Jonides, J., and Perrig, W.J. (2008). Improving fluid intelligence with training on working memory. Proceedings of the National Academy of Sciences of the United States of America (PNAS), May 13, 2008 vol. 105

Summary: Presents evidence of training transfer from a demanding memory task to measure of fluid intelligence (Gf) despite the memory task being very different than Gf test activities. Gf refers to the ability to reason and solve new problems independently of previously acquired knowledge. Training transfer impact thought to be "dosage-dependent" with greater impact occurring with exposure to more training.

Smith, M.E., McEvoy, L.K., and Gevins, A. (1999). Neurophysiological indices of strategy development and skill acquisition. *Cognitive Brian Research,* 7 (3), 389-404.

Summary: Describes task specific practice effects related to a verbal working memory task. This finding was thought to provide neurophysiological evidence for the formation of a task-specific neurocognitive strategy. In addition, these results suggest the EEG can be used to monitor practice-related changes to brain activities associated with specific task processing as well as development of strategies that impact performance.

B.3 Cognitive Load Theory (CLT) References

Overall Summary: Much of the CLT literature is focused on the learning and instruction, however, it may provide an overall approach and measures for determining how good/poor intelligence analysts are processing information, or more precisely, the cognitive effort required to process/analyze the information and make associate decisions.

One measurement technique used by CLT researchers involves the use of (simultaneous) dual-tasks. That is, a secondary task is used to assess the effort required to complete the primary task. Since it is done simultaneously, it can provide a real-time measure of mental effort being expended.

It seems that more proficient IAs will have available to them greater cognitive capacity when completing selected job tasks and would thus be able to complete tasks quicker and with greater accuracy. Part of the reason for this is good analysts might have available to them one or more useful schemas (e.g., for identifying useful info, for developing appropriate problem-solving strategies, etc.).

Individual Article Summaries:

Arino, A.R. (2008). Cognitive load theory and the role of learner experience: An abbreviated review for educational practitioners. *AACE Journal*, 16 (4), 425-439.

Summary: Describes three types of cognitive load sources: Intrinsic, extraneous, and germane. Intrinsic load refers to the number of elements that must be processed simultaneously in working memory. Extraneous load is considered "ineffective" due to it requiring person to engage working memory that is not directly related to a schema. Germane load is considered "effective" due to person able to process information in manner that is relevant to a given schema.

Ippel, M.J. (1996). Cognitive task load and test performance. Paper presented at the International Military Testing Association (IMTA), San Antonio, TX, Nov 12-14, 1996.

Summary: Presents elements of a theory of measurement of the effects of information overload on task performance as measured by accuracy scores. A promising methodology, called the "facet design technique," is also described that may lead to identifying performance profiles based on task facets.

Gwizdka, J. (2010). Using Stroop task to assess cognitive load. *Proceedings of the 2010 European Conference on Cognitive Ergonomics*. Delft, Netherlands, Aug 25-27, 2010.

Summary: Describes use of a Stroop-like task as the secondary task within a dual-task paradigm with the results indicating the ability to reliably identifying extraneous versus intrinsic task load.

Paas, F., Tuovinen, J.E., Tabbers, H., and Van Gerven, P.W. (2003). Cognitive load measurement as a means to advance cognitive load theory. Educational Psychologist, 38 (1), 63-71.

Summary: Describes CLT and learning transfer: That is, transfer of existing knowledge/experience to new situations. According to the authors, the results show how a combination of performance and cognitive load measures are a reliable indicator of mental efficiency of instructional methods.

Sweller, J. (1988) Cognitive load during problem solving: Effects on learning. *Cognitive Science*, 12, 257-285.

Summary: Presents research related to use of means-ends analysis and schema acquisition (tasks) within a dual-task paradigm to more precisely measure cognitive load within a problem solving search situation.

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Appendix C. Standardized Test Summary

This appendix appears in its original form, without editorial change.

Table C-1 contains descriptions of standardized tests that target one or more of the cognitive abilities.

Table C-1. Summary of standardized cognitive ability tests.

Test Name	Attribute Targeted	Test Scores	Test Purpose
"Business Critical Thinking Skills Test"	deductive reasoning, inductive reasoning	Analysis, Inference, Evaluation, Deductive, Inductive, Total.	'Developed to assess the critical thinking skills of business professionals and business students.'
"Aptitude Interest Inventory"	inductive reasoning	Aptitude Based Career Decision Test: 7 scores: Clerical Perception, Vocabulary, Numerical Computation, Numerical Reasoning, Spatial Visualization, Inductive Reasoning, Analytical Reasoning; Interest Based Career Decision Test: ratings in 3 areas: Data, People, Things.	To develop a plan for career exploration.
"Learning Ability Profile"	deductive reasoning, inductive reasoning	Total and 4 derived scores (Certainty, Problem Solving, Flexibility, Frustration).	Designed to provide 'a quantifiable index of the subject's inductive and deductive reasoning, cognitive and problem solving skills'.
"Test of Everyday Reasoning"	deductive reasoning, inductive reasoning	Analysis, Evaluation, Inference, Deductive Reasoning, Inductive Reasoning, Total.	Designed to supplement information on applications for employment, educational assessments, and program evaluations by assessing basic reasoning skills.
"Health Sciences Reasoning Test"	deductive reasoning, inductive reasoning	Analysis, Evaluation, Inference, Deductive Reasoning, Inductive Reasoning, Total.	'Was developed for use by educators and researchers to assess the critical thinking skills of health science professionals and health science students'.

Test Name	Attribute Targeted	Test Scores	Test Purpose
"Cornell Critical Thinking Tests"	deductive reasoning, inductive reasoning	Total score only for each level.	Assesses general critical thinking ability including 'induction, deduction, evaluation, observation, credibility (of statements made by others), assumption identification, and meaning'.
"deductive reasoning test"	deductive reasoning	Total score only.	'Intended as a selection instrument for scientific, entrepreneurial and other high level professional and occupational personnel'.
"Ball Aptitude Battery"	inductive reasoning	Clerical, Analytical Reasoning, Inductive Reasoning, Vocabulary, Numerical Computation, Numerical Reasoning, Paper Folding, Writing Speed, Associative Memory, Auditory Memory Span, Idea Generation, Word Association.	Designed to measure 'various aptitudes needed for successful performance in a wide variety of educational and work settings.'
"Comprehensive Ability Battery"	inductive reasoning, Flexibility of Closure, Originality/Creativity	Verbal Ability (V), Numerical Ability (N), Spatial Ability (S), Speed of Closure (Cs), Perceptual Speed and Accuracy (P), Inductive Reasoning (I), Flexibility of Closure (Cf), Associative Memory (Ma), Mechanical Ability (Mk), Memory Span (Ms), Meaningful Memory (Mm), Spelling (Sp), Auditory Ability (AA), Esthetic Judgment (E), Spontaneous Flexibility (Fs), Ideational Fluency (Fi), Word Fluency (W), Originality (O), Aiming (A), Representational Drawing (RD).	'Features 20 tests, each designed to measure a single primary ability factor . . . important in industrial settings and career and vocational counseling.'
"California Critical Thinking Skills Test"	deductive reasoning, inductive reasoning	Analysis, Inference, Evaluation, Deductive Reasoning, Inductive Reasoning, Total Score.	'Specifically designed to measure the skills dimension of critical thinking.'
"Watson-Glaser Critical Thinking Appraisal"	deductive reasoning	Inference, Recognition of Assumptions, Deduction, Interpretation, Evaluation of Arguments, Total.	Constructed to assess **critical thinking** abilities related to reading comprehension.

Test Name	Attribute Targeted	Test Scores	Test Purpose
"Assessment Inventory for Management "	deductive reasoning, inductive reasoning	Staffing/Recruiting and Selection, Training, Performance Management--Supervision, Business Management, Field Office Development, Interpersonal Relations (Communicating, Counseling, Supporting), Leadership (Delegating, Motivating, Rewarding, Team Building, Networking), Organization (Coordinating, Monitoring, Planning, Problem-Solving and Decision-Making).	'For screening candidates for insurance field management positions.'
"Jouve-Cerebrals Test of Induction"	inductive reasoning	It yields with a Reasoning Index (RIX), an age-referenced standard score that uses a mean of 100, and 15 points per standard deviation.	The JCTI is a computerized nonverbal intelligence test designed with figurative items which don't require acquired knowledge. The JCTI has been developed so that the number of items (up to 52) is individually adapted according to the test-taker's performance. Thanks to the nonverbal nature of its items, this test is suitable for testing persons without cultural bias.
"Emotional Competence Inventory"	Collaboration	Self-Awareness (Emotional Self-Awareness, Accurate Self-Assessment, Self-Confidence); Self-Management (Emotional Self-Control, Transparency, Adaptability, Achievement Orientation, Initiative, Optimism); Social Awareness (Empathy, Organizational Awareness, Service Orientation); Relationship Management (Developing Others, Inspirational Leadership, Influence, Change Catalyst, Conflict Management, Teamwork & **Collaboration**).	'Designed to assess emotional intelligence (the ability to recognize and manage emotions [yours and other]).'
"Lore Leadership Assessment"	Collaboration	Overall Leadership Effectiveness, Moral Leadership, Intellectual Leadership, Courage, **Collaboration**, Visionary/Inspirational.	Designed to 'measure behaviors, skills, and impacts desirable in a leader.'
"Change Abilitator"	Collaboration	Information, Personal, Operational, Impact, **Collaboration**, Transforming.	Designed to identify six types of concern people experience when change is introduced into their organization.

Test Name	Attribute Targeted	Test Scores	Test Purpose
"Assessment of Individual Learning Style: Perceptual Memory Task"	"memory" - Recall, Recognition	7 scores, 3 alternate scores: Spatial Relations, Visual Designs Recognition, Visual Designs-Sequencing, Auditory-Visual Colors Recognition, Auditory-Visual Colors Sequencing, Discrimination Recall, Total PMT, Visual-Visual (alternate), Auditory-Auditory (alternate), Visual-Auditory (alternate).	'To provide measures of the individual's perception and memory for spatial relationships; visual and auditory sequential memory; intermediate term memory; and discrimination of detail'.
"Bloomer Learning Test"	"memory" - Recall	Activity, Response Integration, Boredom, Visual Short-Term Memory, Auditory Short-Term Memory, Visual Apprehension Span, Impulse, Stimulus Complexity, Serial Learning, Recall, Relearning, Learning Set, Free Association, Emotional Ratio, Paired Associate Learning, Paired Associate Decrement, Interference, Concept Recognition, Concept Production, Problem Solving, yielding 3 IQ scores (Simple Learning, Problem Solving, Full Learning)	Identifies 'academic difficulties on the basis of a pattern of strengths and weaknesses in various learning processes
"Kaplan-Baycrest Neuropsychological Assessment"	"memory" - Recall, Recognition	Attention/Concentration, Immediate Memory Recall, Delayed Memory Recall, Delayed Memory Recognition, Spatial Processing, Verbal Fluency, Reasoning/Conceptual Shifting, Total Index.	'Test of neurocognitive functioning.'
"Doors and People: A Test of Visual and Verbal Recall and Recognition "	"memory" - Verbal Memory	Verbal Recall (**People**), Visual Recognition (**Doors**), Visual Recall (Shapes), Verbal Recognition (Names), Overall, Combined Visual Memory, Combined Verbal Memory, Combined Recall, Combined Recognition, Forgetting (Verbal), Forgetting (Visual), Overall Forgetting, Visual-Verbal Discrepancies, Recall-Recognition Discrepancies.	Designed to 'provide comparable measures of visual and verbal memory' and 'test both recall and recognition.'

Test Name	Attribute Targeted	Test Scores	Test Purpose
"Kaufman Short Neuropsychological Assessment Procedure"	"memory" - Recall	Gestalt Closure, Number Recall, Four-Letter Words, Recall/Closure Composite, K-SNAP Composite.	Constructed to assess the 'ability to demonstrate intact mental functioning.'
"Learning Efficiency Test"	"memory" - Recall, Visual Memory	Visual Ordered Recall (Immediate Recall, Short Term Recall, Long Term Recall) Visual Unordered Recall (Immediate Recall, Short Term Recall, Long Term Recall), Auditory Ordered Recall (Immediate Recall, Short Term Recall, Long Term Recall), Auditory Unordered Recall (Immediate Recall, Short Term Recall, Long Term Recall), Total Visual Memory, Total Auditory Memory, Global Memory.	'Yields information about a person's preferred modality for learning and provides insights about the impact of interference on memory storage and retrieval, and the kinds of metacognitive strategies used during learning'.
"Swanson-Cognitive Processing Test"	"memory" - Recall	Rhyming Words, Visual Matrix, Auditory Digit Sequence, Mapping and Directions, Story Retelling, Picture Sequence, Phrase Recall, Spatial Organization, Semantic Association, Semantic Categorization, Nonverbal Sequence, Semantic, Episodic, Total, Auditory, Visual, Prospective, Retrospective, Strategy Efficiency Index, Processing Difference Index, Instructional Efficiency Index, Stability Index.	Designed to assess 'different aspects of mental processing ability and potential.'
"Schaie-Thurstone Adult Mental Abilities Test"	"memory" - Recognition	Recognition Vocabulary, Figure Rotation, Letter Series, Number Addition, Word Fluency, Object Rotation, Word Series.	'Measuring the mental abilities of adults'.
"Non-Verbal Ability Tests"	"memory" - Recall	Matching Shape, Matching Direction, Categorization, Picture Completion, Embedded Figures, Figure Formation, Mazes, Sequencing, Picture Arrangement, Visual Search, Simple Key Test, Complex Key Test, Code Tracking I, Code Tracking II, Visual Recognition, Auditory Recognition, Auditory Recall, Visual Recall, Total.	Designed to measure perceptual, conceptual, attention/concentration, and memory skills.

Test Name	Attribute Targeted	Test Scores	Test Purpose
"Structure of Intellect Learning Abilities Test"	"memory" - Visual Memory	26 subtests in 5 test areas Cognition (Cognition of Figural Units, Cognition of Figural Classes, Cognition of Figural Systems, Cognition of Figural Transformations, Cognition of Symbolic Relations, Cognition of Symbolic Systems, Cognition of Semantic Units, Cognition of Semantic Relations, Cognition of Semantic Systems), Memory (Memory of Figural Units, Memory of Symbolic Units--Visual, Memory of Symbolic Systems--Visual, Memory of Symbolic Units--Auditory, Memory of Symbolic Systems--Auditory, Memory of Symbolic Implications), Evaluation (Evaluation of Figural Units, Evaluation of Figural Classes, Evaluation of Symbolic Classes, Evaluation of Symbolic Systems), Convergent Production (Convergent Production of Figural Units, Convergent Production of Symbolic Systems, Convergent Production of Symbolic Transformations, Convergent Production of Symbolic Implications), and Divergent Production (Divergent Production of Figural Units, Divergent Production of Semantic Units, and Divergent Production of Symbolic Relations) yielding 14 general ability scores Cognition, Memory, Evaluation, Convergent Production, Divergent Production, Figural, Symbolic, Semantic, Units, Classes, Relations, Systems, Transformations, and Implications.	'Designed to assess a wide variety of cognitive abilities or factors of intelligence in children and adults'.
"Concealed Figures"	Flexibility of Closure	Total score	Assesses 'the ability to hold a configuration in mind despite distraction.'
"Visual Patterns Test"	"memory" - Visual Memory	Total score only.	Designed to measure 'short term visual memory.'
"Randt Memory Test"	"memory" - Recall	Acquisition Recall (Five Items Acquisition, Paired Words Acquisition, Short Story Verbatim, Digit Span, Incidental Learning), Delayed Recall (Five Items Recall, Paired Words Recall, Picture Recall, General Information), and Memory Index.	Functions 'as a global survey and evaluation of patients' complaints concerning their memory'.

Test Name	Attribute Targeted	Test Scores	Test Purpose
"Personal Characteristics Inventory"	"memory" - Recognition	Agreeableness (Cooperation, Consideration, Total), Extraversion (Sociability, Need for Recognition, Leadership Orientation, Total), Conscientiousness (Dependability, Achievement Striving, Efficiency, Total), Stability (Even Temperament, Self-Confidence, Total), Openness (Abstract Thinking, Creative Thinking, Total), Occupational Score (Manager, Sales, Clerical, Production, Driver), Teamwork, Integrity, Learning Orientation, Commitment to Work.	Designed to 'help organizations hire more effectively' and provide feedback to employees regarding 'strengths and areas where improvement is necessary'; used in the hiring process and for developmental purposes.
"Reynolds Intellectual Assessment Scales"	"memory" - Verbal Memory	Verbal Intelligence Index (Guess What, Verbal Reasoning), Nonverbal Intelligence Index (Odd-Item Out, What's Missing), Composite Intelligence Index, Composite Memory Index (Verbal Memory, Nonverbal Memory), RIST Index (Guess What, Odd-Item Out).	Designed to assess verbal and nonverbal intelligence and memory.
"Continuous Visual Memory Test"	"memory" - Recognition, Visual Memory	Acquisition (Hits, False Alarms, d-Prime, Total), Delayed Recognition, Visual Discrimination	Constructed to assess recognition memory, perception, and discrimination.
"Memory Assessment Scales"	"memory" - Verbal Memory, Visual Memory	Short-Term Memory (Verbal Span, Visual Span, Total), List Acquisition, Delayed List Recall, Delayed Prose Recall, Global Memory Scale (Verbal Memory [List Recall, Immediate Prose Recall, Total], Visual Memory [Visual Reproduction, Immediate Visual Recognition, Total], Total), Delayed Visual Recognition, Names-Faces (Immediate, Delayed) and 7 Verbal Process scores: Total Intrusions, List Clustering (Acquisition, Recall, Delayed Recall), Cued List Recall (Recall, Delayed Recall), List Recognition.	Developed to assess areas of cognitive function that are involved in memory.

Test Name	Attribute Targeted	Test Scores	Test Purpose
"Test of Memory and Learning"	"memory" - Recall, Recognition, Visual memory, Verbal memory, Concentration	10 Verbal subtest scores (Memory for Stories, Word Selective Reminding, Object Recall, Paired Recall, Digits Forward, Letters Forward, Digits Backward, Letters Backward, Memory for Stories Delayed, Word Selective Reminding Delayed); 6 Nonverbal subtest scores (Facial Memory, Abstract Visual Memory, Visual Sequence Memory, Memory for Location, Visual Selective Reminding, Manual Imitation); 3 core composite scores (Verbal Memory Index, Nonverbal Memory Index, Composite Memory Index); 6 supplemental composite scores (Verbal Delayed Recall Index, Attention/**Concentration** Index, Sequential Recall Index, Free Recall Index, Associative Recall Index, Learning Index).	Designed to assess the 'key features of memory' and to 'evaluate learning as reflected in changes in recall and recognition over multiple trials of various stimuli.'
"Brief Visuospatial Memory Test-Revised"	"memory" - Recall, Recognition, Visual Memory	Total Recall, Learning, Delayed Recall, Percent Retained, Recognition Hits, Recognition False Alarms, Recognition Discrimination Index, Recognition Response Bias, Copy (Optional)	Designed as an equivalent, multiple-test form assessment of visual memory.
"Rey Complex Figure Test and Recognition Trial"	"memory" - Recall	Immediate Recall, Delayed Recall, Recognition Total Correct, Copy, Time to Copy, Recognition True Positives, Recognition False Positives, Recognition True Negatives, Recognition False Negatives.	Designed to 'investigate visuospatial constructional ability and visual memory.'
"Leiter International Performance Scale-Revised"	"memory" - Recognition	Visualization and Reasoning (Figure Ground, Design Analogies, Form Completion, Matching, Sequential Order, Repeated Patterns, Picture Context, Classification, Paper Folding, Figure Rotation), VR Composite (Fluid Reasoning, Brief IQ, Fundamental Visualization, Spatial Visualization, Full IQ), Attention and Memory Associated Pairs, Immediate Recognition, Forward Memory, Attention Sustained, Reverse Memory, Visual Coding, Spatial Memory, Delayed Pairs, Delayed Recognition, Attention Divided), AM Composite (Memory Screen, Associative Memory, Memory Span, Attention, Memory Process, Recognition Memory).	Constructed as a 'nonverbal cognitive assessment.'

Test Name	Attribute Targeted	Test Scores	Test Purpose
"Wide Range Assessment of Memory and Learning"	"memory" - Recall, Recognition, Verbal Memory, Visual Memory	Verbal Memory (Story Memory, Verbal Learning, Total), Visual Memory (Design Memory, Picture Memory, Total), Attention/Concentration (Finger Windows, Number Letter, Total), General Memory; Optional scores: Working Memory (Verbal Working Memory, Symbolic Working Memory, Total), Verbal Recognition (Story Recognition, Verbal Learning Recognition, Total), Visual Recognition (Design Recognition, Picture Memory Recognition, Total), General Recognition, Sound Symbol, Sentence Memory, Story Memory Recall, Verbal Learning Recall, Sound Symbol Recall.	Designed for use in 'clinical assessments of memory including evaluation of immediate and/or delay recall as well as differentiating between verbal, visual or more global memory deficits.'
"Repeatable Battery for the Assessment of Neuropsychological Status"	"memory" - Recall, Recognition	Immediate Memory (List Learning, Short Memory, Total), Visuospatial/Constructional (Figure Copy, Line Orientation, Total), Language (Picture Naming, Semantic Fluency, Total), Attention (Digit Span, Coding, Total), Delayed Memory (List Recall, List Recognition, Story Memory, Figure Recall, Total), Total.	Designed to measure 'attention, language, visuospatial/constructional abilities, and immediate and delayed memory.'
"Delis-Kaplan Executive Function System"	"memory" - Recognition	Visual Scanning, Number Sequencing, Letter Sequencing, Number-Letter Switching, Motor Speed, Composite Score, Letter Fluency, Category Fluency, Category Switching, Filled Dots, Empty Dots Only, Switching, Color Naming, Word Reading, Inhibition, Inhibition/Switching, Free Sorting, Sort Recognition, Total Achievement Score, Initial Abstraction Score, Total Consecutively Correct	To 'comprehensively assess ... the key components of executive functions believed to be mediated primarily by the frontal lobe
"Benton Visual Retention Test"	"memory" - Visual Memory	Omissions, Distortions, Perseverations, Rotations, Misplacements, Size Errors, Total Left, Total Right, Total	To assess visual perception, visual memory, and visuoconstructive abilities

Test Name	Attribute Targeted	Test Scores	Test Purpose
"California Verbal Learning Test"	"memory" - Recall, Recognition	Immediate Recall (Trial 1, Trials 2-5, Trials 1-5 Total), Learning Slope, Semantic Clustering, Serial Clustering, Subjective Clustering, Primacy/Recency Recall, Percentage of Recall Consistency, List B Trial, Proactive Interference, Short-Delay Free Recall, Retroactive Interference, Short-Delay Cued Recall, Long-Delay Free Recall, Long-Delay Free Recall Retention, Long-Delay Cued Recall, Repetition Errors, Synonym/Subordinate Intrusions, Across-List Intrusions, Categorical Intrusions, Non-Categorical Intrusions, Yes/No Recognition Testing, False-Positive Errors, Total Recognition Discriminability, Source Recognition Discriminability, Semantic Recognition Discriminability, Novel Recognition Discriminability, Response Bias, Critical Item Analysis, Forced-Choice Recognition [optional].	To 'obtain a detailed and comprehensive assessment of verbal learning and memory.'
"Wechsler Memory Scale"	"memory" - Recall, Verbal Memory, Visual Memory	6 primary (Logical Memory I, Logical Memory II, Verbal Paired Associates I, Verbal Paired Associates II, Designs I, Designs II [Adult battery only], Visual Reproduction I, Visual Reproduction II, Spatial Addition [Adult battery only], Symbol Span; 1 optional (Brief Cognitive Status Exam); Five indices (Auditory Memory, Visual Memory, Visual Working Memory [Adult battery only], Immediate Memory, Delayed Memory.	Developed to 'assess various memory and working memory abilities' among 'individuals with suspected memory deficits or diagnosed with a range of neurological, psychiatric, and developmental disorders.'
"Mini-Mental State Examination"	"memory" - Recall	Total score only with items in 11 sections: Orientation to Time, Orientation to Place, Registration, Attention and Calculation, Recall, Naming, Repetition, Comprehension, Reading, Writing, Drawing.	Designed to 'measure cognitive status in adults.'
"Hopkins Verbal Learning Text-Revised"	"memory" - Recall, Recognition	Total Recall, Delayed Recall, Retention, Recognition Discrimination Index	A 'brief assessment of verbal learning and memory (immediate recall, delayed recall, delayed recognition).'
"CNS Vital Signs Screening Battery"	"memory" - Verbal Memory, Visual Memory	Memory, Mental Speed, Reaction Time Attention, Cognitive Flexibility for 7 subtests: Verbal Memory, Visual Memory, Finger Tapping, Symbol Digit Coding, Stroop, Shifting Attention, continuous Performance.	Designed to 'assess neurocognitive state.'

Test Name	Attribute Targeted	Test Scores	Test Purpose
"profile of creative abilities"	Originality/Creativity, Problem Sensitivity	Creativity Index, Drawing (New Elements, Originality, Orientation, Perspectives, Total), Categories (Fluency, Flexibility, Total), Home Rating Scale Total, School Rating Scale Total.	'Designed to measure the creative abilities of students.'
"Meyer-Kendall Assessment Survey"	perseverance	Objectivity, Social Desirability Bias, Dominance, Extraversion, People Concerns, Attention to Detail, Anxiety, Stability, Psychosomatic Tendencies, Determination, Achievement Motivation, Independence.	Constructed to assess work-related personality style.
"Work Personality Index"	perseverance	Teamwork, Concern for Others, Outgoing, Democratic, Attention to Detail, Rule-Following, Dependability, Ambition, Energy, **Persistence**, Leadership, Innovation, Analytic Thinking, Self-Control, Stress Tolerance, Initiative, Flexibility, Achievement, Conscientiousness, Social Orientation, Practical Intelligence, Adjustment.	'Designed to identify personality traits that directly relate to work performance.'
"Inventory for Counseling & Development"	perseverance, Originality/Creativity	Agreement, Favorable Impression, Infrequent, Insecurity, Alienation, Exam Tension, Ambition, **Persistence**, Practicality, Sociability, Teacher-Student Interaction, Intellectuality, Originality, Adaptability, Orderliness, Liberal-Conservative, Socio-Political Interest, Sexual Beliefs, Sex Role Differences, Academic Performance, Academic Excellence, Academic Capacity, Academic Motivation.	An attempt to identify 'strengths, assets and coping skills of college students seeking assistance with vocational, educational and personal problems'.
"Poppleton Allen Sales Aptitude Test"	perseverance	Administrative Effectiveness, Social Sophistication, Emotional Resilience, Dynamism, Economic Motivation, Empathy, Competitiveness, Organizational Ability, Work Commitment, Emotional Stability, Self-sufficiency, Verbal Fluency, Determination, Self-confidence, Entertaining	'Designed to measure those attributes which are of importance for effective selling.'
"Occupational Personality Assessment"	perseverance	Interest Profile, Experience Profile, How Much Interest and Experience Match, Focus on Making Money, Tactical Orientation, Reading Business Tables, Commercial Orientation, Personal Motives, Peaceful, Sensory, Acquisitive, Work Driven, Work Motives, Intellect, Beauty, Independent Authority, Pleasing Others, Aggressiveness, Field Independence, Toughness, Determination, Fluctuating Salary, Fluctuating Income Tolerance, Management Style Preference.	Designed as a 'computer simulation of a vocational assessment.'

Test Name	Attribute Targeted	Test Scores	Test Purpose
"Howarth Personality Questionnaire"	perseverance	Sociability, Anxiety, Dominance, Conscience, Hypochondriac-Medical, Impulsive, Cooperative-Considerateness, Inferiority, **Persistence**, Suspicion vs. Trust.	To measure personality dimensions.
"Athletic Motivation Inventory"	perseverance	Drive, Aggressiveness, Determination, Responsibility, Leadership, Self-Confidence, Emotional Control, Mental Toughness, Coachability, Conscientiousness, Trust, Validity Scales (Accuracy, Desirability, Completion Rate).	Constructed to measure the personality and motivation of athletes participating in competitive sports.
"Basic Attributes Test"	Timesharing	5 tests including Two Hand Coordination (psychomotor), Complex Coordination (psychomotor), Item Recognition (short term memory), Time Sharing (psychomotor), and Activities Interest Inventory (attitudes)	A computerized test battery used by the US Air Force for pilot selection
"Achievement Motivation Inventory"	perseverance	Compensatory Effort, Competitiveness, Confidence in Success, Dominance, Eagerness to Learn, Engagement, Fearlessness, Flexibility, Flow, Goal Setting, Independence, Internality, **Persistence**, Preference for Difficult Tasks, Pride in Productivity, Self-Control, Status Orientation.	Designed to evaluate 'all major aspects of job-related achievement motivation.'
"Work Personality Profile"	perseverance	Acceptance of Work Role, Ability to Profit from Instruction or Correction, Work **Persistence**, Work Tolerance, Amount of Supervision Required, Extent Trainee Seeks Assistance from Supervisor, Degree of Comfort or Anxiety with Supervisor, Appropriateness of Personal Relations with Supervisor, Teamwork, Ability to Socialize with Co-Workers, Social Communication Skills, Task Orientation, Social Skills, Work Motivation, Work Conformance, Personal Presentation.	Designed to 'assess fundamental work role requirements that are essential to achievement and maintenance of suitable employment'.
"Life Style Questionnaire"	perseverance	Expressive/Imaginative, Logical/Analytical, Managerial/Enterprising, Precise/Administrative, Active/Concrete, Supportive/Social, Risk Taking/Uncertainty, **Perseverance**/Determination, Self-Evaluation, Sensitivity/Other Awareness, Affiliation, Degree to Which a Vocation is Associated with Self Fulfillment, Degree of Certainty.	To provide information regarding vocational interests and attitudes.
"alternate uses test"	Fluency of Ideas	Total score only.	Designed to represent an expected factor of 'flexibility of thinking' in an investigation of creative thinking.'

Test Name	Attribute Targeted	Test Scores	Test Purpose
"The New York Longitudinal Scales Adult Temperament Questionnaire"	perseverance	Activity, Rhythmicity, Adaptability, Threshold, Approach, Distractibility, Intensity, **Persistence**, Mood.	Measures temperament in adulthood.
"Creativity Assessment Packet"	Originality/Creativity	Fluency, Flexibility, Originality, Elaboration, Titles, Divergent Thinking, Curiosity, Imagination, Complexity, Risk-Taking, Fluency, Flexibility, Originality, Elaboration, Curiosity, Imagination, Complexity, Risk-Taking.	To assess creative potential.
"Abbreviated Torrance Test for Adults"	Originality/Creativity	Norm-Referenced Measures (Fluency, Originality, Elaboration, Flexibility, Total Scaled Score), Criterion-Referenced Creativity Indicators (Richness and Colorfulness of Imagery, Emotions/Feelings, Future Orientation, Humor: Conceptual Incongruity, Provocative Questions, Verbal Responses Total, Openness: Resistance to Premature Closure, Unusual Visualization/Different Perspective, Movement and/or Sound, Richness and/or Colorfulness of Imagery, Abstractness of Titles, Articulateness in Telling Story, Combination/Synthesis of Two or More Figures, Internal Visual Perspective, Expressions of Feelings and Emotions, Fantasy, Figural Responses Total), Creativity Index.	To assess creative thinking ability.
"Kirton Adaption-Innovation Inventory"	Originality/Creativity	Sufficiency v. Proliferation of Originality, Efficiency, Rule/Group Conformity, Total.	A measure of a person's preference for, or style of, creativity, problem solving, and decision making.
"Torrance Tests of Creative Thinking"	Originality/Creativity	Verbal, Figural, Fluency, Flexibility, Originality, Elaboration.	To identify and evaluate **creative** potential.

Test Name	Attribute Targeted	Test Scores	Test Purpose
"Manchester Personality Questionnaire"	Originality/Creativity	Creativity, Achievement, Agreeableness, Extroversion, Resilience, Originality, Rule Consciousness, Openness to Change, Assertiveness, Social Confidence, Empathy, Communicativeness, Independence, Rationality, Competitiveness, Conscientiousness, Perfectionism, Decisiveness, Apprehension, Radicalness, Response Style.	Designed to provide an occupational personality test with a focus on traits relevant to creative and innovative behavior.
"Kaplan-Baycrest Neuropsychological Assessment"	Selective Attention, Concentration	Attention/Concentration, Immediate Memory Recall, Delayed Memory Recall, Delayed Memory Recognition, Spatial Processing, Verbal Fluency, Reasoning/Conceptual Shifting, Total Index.	'Test of neurocognitive functioning.'
"California Computerized Assessment Package"	Selective Attention	Simple Reaction Time, Choice Reaction Time for Single Digits, Serial Pattern Matching, Lexical Discrimination, Visual Selective Attention, Response Reversal and Rapid Visual Scanning, Form Discrimination.	Designed as a 'standardized assessment of reaction time and speed of information processing.'
"Test of Attention"	Selective Attention, Concentration	Total Number of Items Processed (TN), Errors (E), Percentage of Error (E%), Total Number of Items Processed Minus Errors (TN-E), **Concentration** Performance (CP), Fluctuation Rate (FR), and Skipping Syndrome (S-Syndrome)	The d2 Test is essentially a letter cancellation task intended to assess selective attention; it also measures sustained attention and speed of processing.
"Useful Field of View "	Selective Attention	Central Vision and Processing Speed, Divided Attention, Selective Attention.	Designed as a 'computer-administered and computer-scored test of visual attention,' which may be used to help predict the degree to which a person may perform some everyday activities, such as driving a motor vehicle, safely.
"Ruff 2 & 7 Selective Attention Test"	Selective Attention	Automatic Detection Speed, Automatic Detection Errors, Automatic Detection Accuracy, Controlled Search Speed, Controlled Search Errors, Controlled Search Accuracy, Total Speed, Total Accuracy, Speed Difference, Accuracy Difference, Total Difference.	Developed to 'measure two overlapping aspects of visual attention: sustained attention and selective attention.'

Test Name	Attribute Targeted	Test Scores	Test Purpose
"Test of Everyday Attention"	Selective Attention	Map Search, Elevator Counting, Elevator Counting with Distraction, Visual Elevator, Elevator Counting with Reversal, Telephone Search, Telephone Search While Counting, Lottery, Total.	To measure 'selective attention, sustained attention and attentional switching.'
"Auditory Selective Attention Test"	Selective Attention	Total Errors.	'To measure selective attention.'
"Visual Search and Attention Test"	Selective Attention	Left, Right, Total.	Constructed to assess 'ability to scan accurately and [to] sustain attention on each of four different visual cancellation tasks'.

Test Name	Attribute Targeted	Test Scores	Test Purpose
Test of Memory and Learning	Concentration	10 Verbal subtest scores (Memory for Stories, Word Selective Reminding, Object Recall, Paired Recall, Digits Forward, Letters Forward, Digits Backward, Letters Backward, Memory for Stories Delayed, Word Selective Reminding Delayed); 6 Nonverbal subtest scores (Facial Memory, Abstract Visual Memory, Visual Sequence Memory, Memory for Location, Visual Selective Reminding, Manual Imitation); 3 core composite scores (Verbal Memory Index, Nonverbal Memory Index, Composite Memory Index); 6 supplemental composite scores (Verbal Delayed Recall Index, Attention/**Concentration** Index, Sequential Recall Index, Free Recall Index, Associative Recall Index, Learning Index).	Designed to assess the 'key features of memory' and to 'evaluate learning as reflected in changes in recall and recognition over multiple trials of various stimuli.'
Wide Range Assessment of Memory and Learning	Concentration	Verbal Memory (Story Memory, Verbal Learning, Total), Visual Memory (Design Memory, Picture Memory, Total), Attention/Concentration (Finger Windows, Number Letter, Total), General Memory; Optional scores: Working Memory (Verbal Working Memory, Symbolic Working Memory, Total), Verbal Recognition (Story Recognition, Verbal Learning Recognition, Total), Visual Recognition (Design Recognition, Picture Memory Recognition, Total), General Recognition, Sound Symbol, Sentence Memory, Story Memory Recall, Verbal Learning Recall, Sound Symbol Recall.	Designed for use in 'clinical assessments of memory including evaluation of immediate and/or delay recall as well as differentiating between verbal, visual or more global memory deficits.'
Learning and Study Strategies Inventory	Concentration	Anxiety Scale, Attitude Scale, **Concentration** Scale, Information Processing Scale, Motivation Scale, Self-Testing Scale, Selecting Main Ideas Scale, Study Aids Scale, Time Management Scale, Test Strategies Scale.	Designed to assess 'students' awareness about and use of learning and study strategies related to skill, will and self-regulation components of strategic learning.'
The Attentional and Interpersonal Style Inventory	Concentration	Attentional (Broad External Awareness, External Distractibility, Conceptual/Analytical, Internal Distractibility, Narrow/Focused, Reduced Flexibility), Interpersonal (Information Processing, Orientation Toward Rules and Risk/Impulse Control, Need for Control, Self Esteem, Physical Competitiveness, Decision Making Speed, Extroversion, Introversion, Expression of Ideas, Expression of Criticism, Expression of Support, Self-Critical).	'Developed to measure the critical **concentration** and interpersonal determinants of performance.'

Test Name	Attribute Targeted	Test Scores	Test Purpose
START--Strategic Assessment of Readiness for Training	Concentration	Anxiety, Attitude, Motivation, **Concentration**, Identifying Important Information, Knowledge Acquisition Strategies, Monitoring Learning, Time Management.	Designed to diagnose adult's learning strengths and weaknesses.
Wechsler Memory Scale	Concentration	Verbal Memory (Logical Memory I, Verbal Paired Associates I, Total), Visual Memory (Figural Memory, Visual Paired Associates I, Visual Reproduction I, Total), Total General Memory, Attention/**Concentration** (Mental Control, Digit Span, Visual Memory Span, Total), Delayed Recall (Logical Memory II, Visual Paired Associates II, Verbal Paired Associates II, Visual Reproduction II, Total), Information and Orientation	Constructed to assess 'memory for verbal and figural stimuli, meaningful and abstract material, and delayed as well as immediate recall.'
Non-Verbal Ability Tests	Concentration	Matching Shape, Matching Direction, Categorization, Picture Completion, Embedded Figures, Figure Formation, Mazes, Sequencing, Picture Arrangement, Visual Search, Simple Key Test, Complex Key Test, Code Tracking I, Code Tracking II, Visual Recognition, Auditory Recognition, Auditory Recall, Visual Recall, Total.	Designed to measure perceptual, conceptual, attention/**concentration**, and memory skills.

Appendix D. Effects Matrix Summary

Table D-1 contains descriptions of effects matrices that target one or more of the cognitive abilities. In the table, N represents the number of correlations used in the summary effect. Fisher's Z with standard error of Z is in parentheses.

Each demand group represents the coding of an experimental task that was correlated with a measure of the personnel attribute by a standardized test. For example, there were four data points mined from studies that correlated scores on a standardized test for flexibility of closure with a task that was coded as imposing deductive and inductive demand. In order to find the mean correlation across those four data points, r was converted to z (Z takes into account the sample size). Then the mean z was computed and is shown in the table with the standard error of z in parentheses. Demand groups relate to personnel attributes by z, which is a standardized measure of r, and essentially represents the strength of association between a score on standardized tests that measure the personnel attribute and some measure of performance on the experimental task.

Table D-1. Effects matrices that target one or more of the cognitive abilities.

Demand Groups	Measurable Personnel Attributes												
	Analytical Thinking / Reasoning (18)	Collaboration (2)	Creativity/Originality (10)	Critical Thinking (36)	Deduction (31)	Flexibility of Closure (64)	Fluency of Ideas (10)	Induction (1)	Inference (7)	Memory-Recall (31)	Memory-Recognition (24)	Motivation/Perseverance (1)	Spatial Rotation (8)
Deductive, Inductive	*	*	N=1 .1(.04)	*	*	N=4 .33(.02)	N=1 -.01(.04)	*	*	*	*	*	*
Deductive, Inductive, Flexibility of Closure	N=1 .18(.15)	*	*	N=1 .68(.22)	*	N=2 .29(.09)	*	*	*	N=2 -.03(.09)	N=2 .1(.09)	*	*
Deductive, Inductive, Memorization	N=2 .35(.09)	*	*	*	N=2 .35(.09)	*	*	*	N=1 .42(.11)	N=1 .37(.11)	*	*	N=1 -.13(.12)
Deductive, Inductive, Problem Sensitivity	*	*	*	N=1 1.16(.21)	*	*	*	*	*	*	*	*	*
Deductive, Inductive, Organization of Information	*	*	*	N=4 -.07(.08)	*	*	*	*	*	*	*	*	*
Deductive, Flexibility of Closure	N=1 .44(.15)	*	*	*	*	N=2 .16(.09)	*	*	*	N=2 .04(.09)	N=2 .11(.09)	*	*
Deductive, Flexibility of Closure, Problem Sensitivity	*	*	*	*	*	N=2 .46(.09)	*	*	*	N=2 .25(.09)	N=2 .23(.09)	*	*
Deductive, Flexibility of Closure, Creativity	*	*	*	N=2 -.48(.19)	*	*	*	*	*	*	*	*	*
Deductive, Memorization, Organization of Information	*	*	*	N=8 .06(.06)	N=1 .23(.12)	*	*	*	*	*	*	*	*
Deductive, Problem Sensitivity	*	*	*	*	N=5 .3(.04)	*	*	*	*	*	*	*	*

Demand Groups	Measurable Personnel Attributes												
	Analytical Thinking / Reasoning (18)	Collaboration (2)	Creativity/Originality (10)	Critical Thinking (36)	Deduction (31)	Flexibility of Closure (64)	Fluency of Ideas (10)	Induction (1)	Inference (7)	Memory-Recall (31)	Memory-Recognition (24)	Motivation/Perseverance (1)	Spatial Rotation (8)
Deductive, Problem Sensitivity, Organization of Information	*	*	*	N=1 .48(.06)	*	*	*	*	*	*	*	*	*
Deductive, Organization of Information	*	*	*	N=6 .14(.01)	N=2 .01(.1)	*	*	*	*	*	*	*	*
Inductive, Flexibility of Closure	N=1 .34(.15)	*	*	N=1 .54(.1)	*	*	*	*	*	*	*	*	*
Inductive, Flexibility of Closure, Problem Sensitivity	*	*	*	N=4 .29(.08)	*	*	*	*	*	*	*	*	*
Inductive, Flexibility of Closure, Organization of Information	*	*	*	N=2 .33(.11)	*	*	*	*	*	*	*	*	*
Inductive, Memorization	N=4 .47(.06)	*	*	*	N=4 .34(.06)	*	*	*	N=3 .35(.07)	N=3 .49(.07)	*	*	N=3 -.01(.07)
Inductive, Fluency of Ideas, Creativity	*	N=1 .94(.19)	*	*	*	*	*	*	*	*	*	*	*
Collaboration	*	*	*	N=1 -.3(.35)	*	*	*	*	*	*	*	N=1 .62(.03)	*
Collaboration, Memorization, Problem Sensitivity	*	*	*	N=1 .19(.09)	*	*	*	*	*	*	*	*	*
Flexibility of Closure	N=1 .41(.15)	*	N=7 .1(.02)	*	*	N=24 .22(.01)	N=7 .04(.02)	*	*	*	*	*	*

Demand Groups	Measurable Personnel Attributes												
	Analytical Thinking / Reasoning (18)	Collaboration (2)	Creativity/Originality (10)	Critical Thinking (36)	Deduction (31)	Flexibility of Closure (64)	Fluency of Ideas (10)	Induction (1)	Inference (7)	Memory-Recall (31)	Memory-Recognition (24)	Motivation/Perseverance (1)	Spatial Rotation (8)
Flexibility of Closure, Memorization	*	*	*	*	*	N=2 .3(.09)	*	*	*	N=4 .22(.06)	N=3 .22(.07)	*	*
Flexibility of Closure, Memorization, Organization of Information	N=2 .55(.09)	*	*	N=2 .01(.08)	N=5 .15(.06)	*	*	*	*	*	*	*	N=1 .11(.12)
Flexibility of Closure, Problem Sensitivity, Perseverance	*	*	*	N=2 .01(.09)	*	*	*	*	*	*	*	*	*
Flexibility of Closure, Fluency of Ideas	*	*	*	*	*	N=2 .11(.09)	*	*	*	N=2 -.03(.09)	N=2 .02(.09)	*	*
Flexibility of Closure, Fluency of Ideas, Creativity	N=1 .32(.15)	*	*	*	*	N=2 .52(.09)	*	*	*	N=2 .21(.09)	N=2 .41(.09)	*	*
Flexibility of Closure, Timesharing	*	*	N=1 .08(.04)	*	*	N=4 .21(.02)	N=1 .23(.04)	*	*	*	*	*	*
Memorization	N=2 .44(.09)	*	*	*	N=2 .37(.09)	*	*	*	N=1 .47(.11)	N=1 .54(.11)	*	*	N=1 -.09(.12)
Memorization, Organization of Information	N=3 .28(.07)	*	*	*	N=3 .31(.07)	N=6 .25(.05)	*	*	N=2 .38(.08)	N=6 .29(.05)	N=5 .17(.06)	*	N=2 .17(.09)
Memorization, Organization of Information, Selective Attention	*	*	*	*	N=4 .59(.09)	*	*	*	*	*	*	*	*

Demand Groups	Measurable Personnel Attributes												
	Analytical Thinking / Reasoning (18)	Collaboration (2)	Creativity/Originality (10)	Critical Thinking (36)	Deduction (31)	Flexibility of Closure (64)	Fluency of Ideas (10)	Induction (1)	Inference (7)	Memory-Recall (31)	Memory-Recognition (24)	Motivation/Perseverance (1)	Spatial Rotation (8)
Memorization, Timesharing, Selective Attention	*	*	*	*	*	N=2 .36(.09)	*	*	*	N=2 .23(.09)	N=2 .21(.09)	*	*
Memorization, Creativity	*	*	*	*	*	N=2 .46(.09)	*	*	*	N=2 .15(.09)	N=2 .25(.09)	*	*
Problem Sensitivity	*	*	*	*	N=1 -.41(.16)	*	*	*	*	*	*	*	*
Problem Sensitivity, Organization of Information, Timesharing	*	*	*	*	*	N=2 .18(.09)	*	*	*	N=2 .06(.09)	N=2 .2(.09)	*	*
Organization of Information, Fluency of Ideas, Creativity	*	*	*	*	N=1 .04(.13)	*	*	N=1 .01(.13)	*	*	*	*	*
Organization of Information, Timesharing	*	*	*	*	N=1 .3(.25)	*	*	*	*	*	*	*	*
Perseverance	*	N=1 .62(.03)	*	*	*	*	*	*	*	*	*	*	*
Fluency of Ideas	*	*	N=1 .03(.04)	*	*	N=4 .04(.02)	*	*	*	*	*	*	*
Fluency of Ideas, Creativity	*	*	*	*	*	N=4 .12(.02)	N=1 .03(.04)	*	*	*	*	*	*

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Appendix E. Detailed Task Data Used for Model Development

Table E-1 contains the ratings given by the four subject matter experts. In some cases an ability was not rated, but that should not infer that it is not critical overall.

SMEs provided information about the subtasks conducted during the course of performing an Evaluate the Threat task. The time duration taken to perform these subtasks, along with their frequency of occurrence, is provided in table E-2. A distinction was made to differentiate full-spectrum operations from stability and support operations since some of the subtasks involve a significantly different amount of effort depending on the type of operating being worked.

Table E-1. Subject matter expert ratings of ability importance to task.

Activity (or Task): Evaluate the threat	**Ability (see descriptions)**									
Needed to perform the activity: **1 = a minimum amount is needed** **4 = a moderate amount is needed** **7 = a great amount is needed**	1. Memorization	2. Selective Attention	3. Time Sharing	4. Deductive Reasoning	5. Inductive Reasoning	6. Problem Sensitivity	7. Flexibility of Closure	8. Fluency of Ideas	9. Originality	10. Perseverance
20/30/40: Prioritization of tasks		6 7 6 6	7 6 5 6			4 6 4			4 4	5 4
10: Identify METT-TC effects on threat forces	4	4	5	6	5	3	2	1	1	2
40: Verify METT-TC effects on threat forces	3	4	5	5	5	3	2	1	1	1
10; Vpdate COP with current enemy composition	5	4	5	5	6	6	6	6	3	5
40: Validate COP with current enemy composition	5	4	5	5	5	5	6	6	4	6
10: Develop Link Diagrams, Association Matrices, Activity Matrices, and TEC	3	4	6	6	6	6	6	5	5	5
30: Verify Link Diagrams, Association Matrices, Activity Matrices, and TEC	4 3	6 6 4	6	5 5 6	5 6 6 6	6 6 6	5 6 6	5 4 5	5 5 5	4 5 5
40: Analyze Link Diagrams, Association Matrices, Activity Matrices, and TEC	7	6	7	7	7	7	7	6	6	7
20: Incorporate the elements (battlefield geography and environment conditions) by understanding the elements of the environment and how they affect the battle.	5 5 6 4	4	5	6 6 5 4	6 4	7 4	4	6 2	1	4 1
40: Verify the elements have been incorporated into the threat model.	1	2	2	3	1	3	1	1		2
10: Identify gaps in intelligence holdings	7	6	7	5	6	6				7

Activity (or Task): Evaluate the threat	**Ability (see descriptions)**									
Needed to perform the activity: **1 = a minimum amount is needed** **4 = a moderate amount is needed** **7 = a great amount is needed**	1. Memorization	2. Selective Attention	3. Time Sharing	4. Deductive Reasoning	5. Inductive Reasoning	6. Problem Sensitivity	7. Flexibility of Closure	8. Fluency of Ideas	9. Originality	10. Perseverance
40: Verify gaps in intelligence holdings	7	6	7	5	6	6				7
10: Identify threat capabilities	7	7	7	6	7	7				6
10: Draft threat assessments to develop realistic threat models	7	6	7	6	7	7				6
Create threat assessments to develop realistic threat models	3 7	6	7	5 5 4 7	6 6 7	6 6 7	5 6	7 7 6		7
Develop enemy OB/structure	7 6 6 7	6	7	6 5 5 6	6 7 7 7	7				7
40: Verify enemy OB/structure	7	6	7	6	7	7				7
Develop threat capabilities statement in Full Spectrum is focused on units	6 4 7	6	7	7 6 7	6 7	6 7	6 6 6	6 5	4	6 7
Develop threat capabilities statement in Stability and Support is focused on individual or small group level sustainment capabilities	7 6 5 7	6	7	6 6 5 6	6 6 7	7		6	6 7 6	6 7
40: Verify threat capabilities statement	7	6	7	6	7	7				7
Identify relevant databases	7 6 7	7	7	5 5 4	7	5 4 4	7	5	5	6 7

Activity (or Task): Evaluate the threat	**Ability (see descriptions)**									
Needed to perform the activity: **1 = a minimum amount is needed** **4 = a moderate amount is needed** **7 = a great amount is needed**	1. Memorization	2. Selective Attention	3. Time Sharing	4. Deductive Reasoning	5. Inductive Reasoning	6. Problem Sensitivity	7. Flexibility of Closure	8. Fluency of Ideas	9. Originality	10. Perseverance
Analyze intelligence holding IOT identify existing or emerging enemy TTPs	6 7	6 7	7	7 6 5 7	6 7 7	7	7	6 6 6	5 4 6	7
Develop initial ECOAs based upon indicators and historical TTPs	5 6 7	6 7	7	6 7 7	6 6 5 7	7	5 7	6 6 5 6	6 5	7
40: Verify initial ECOAs based upon indicators and historical TTPs	7	7	7	7	7	7	7	6	3	7
Depict the composition and array of enemy network in an AO, AI, and AOI based on operational variables (PMESII-PT ASCOPE) and TTPs.	6 3 7	5	7	6 5 7	6 6 6 7	7	7	2 4	4	6 6 6 7
20: Develop RFIs	5 5	4	5 4	7 6 5	6 6 4	5	6	3	5 4	7
30: Compile RFIs	6	4	4		6			3	3	7
Develop HVI/HVT/HPTs	6 7	4 5 5	7	6 6 5 7	6 7	6 6 7	7	5	6 5 5	6 7
Validate HVI/HVT/HPTs	7	7	7	7	7	7	7	7	3	7

Table E-2. Evaluate the Threat subtask occurrences.

Task	Activity (or Task)	Task Time	Performance Levels	Operation	Task Duration				Frequency of Occurrence			
			Performance is considered to be either: 1) satisfactory or unsatisfactory, or 2) on a scale of quality such as one that ranges from inadequate, through poor, OK, good, excellent?		**SL 10**	**SL 20**	**SL 30**	**SL 40**	**SL 10**	**SL 20**	**SL 30**	**SL 40**
1	Prioritization of tasks	Sporadically all the time, as needed. Seconds to a few minutes.	inadequate, through poor, OK, good, excellent	all		10 sec - 3-5 mins				Sporadically all the time		
2	Depict the composition and array of enemy network in an AO, AI, and AOI based on operational variables (PMESII-PT ASCOPE) and TTPs.	FSO is quick and easy. Characteristics of enemy are known. On a 12-hr shift it might take 1-2 hr, or more detail may need more based on Cmdr needs. Company may take 3-4 hrs. Battalion 1-2 hrs due to capture two echelons below you.	Creating and presenting products that meet Cmdrs rqts and needs. Accuracy and relevant with backup. This is the major presentation to the Cmdr every 12 hrs. About .25 % of time there is a lack info/support	FSO	1-2 hrs				12-24 hrs			
		SSO is ongoing each time a new person, weapon shows up. As time goes by you develop a knowledge of the community fills in.		SSO	10-20 mins				ongoing			
3	Develop RFIs	Fill in a form, identify gaps (this can take time 2-3 hrs, to coalesce), request in a manner that is specific and answerable. As the gaps get smaller the time can get down to ~1 hr.	Gap is found or not found. Request is not well formed. Gap is not adequately investigated or understood.	all		1-3 hrs				2-4 per wk		
4	Update COP with current enemy composition			all	1-2 hrs							
5	Develop HVI/HVT/HPTs. This is part of Operations Planning. Done mainly at night. Prioritize the weapons. This is a preparatory task that can take many hours. Prioritization. Conservation of assets – take out the radar vs the six weapon systems supported by it.	FSO are known capabilities		FSO	0				0			
		SSO are individual and weapon based, ongoing. Could take weeks or month overall.		SSO	1-3 hrs				ongoing			
6	Verify gaps in intelligence holdings			all				15-60 min				every 2-6 wks
7	Identify relevant databases	Really more of a knowledge base gained over the years. Minutes to .5 to 2-3 hrs (maybe 10% of the time)	Poor, good, very good, great. Gather a set of databases or even create their own.	all	3-5 min to 2-3 hrs				10%			

Task	Activity (or Task)	Task Time	Performance Levels	Operation	Task Duration				Frequency of Occurrence			
			Performance is considered to be either: **1) satisfactory or unsatisfactory, or** **2) on a scale of quality such as one that ranges from inadequate, through poor, OK, good, excellent?**		**SL 10**	**SL 20**	**SL 30**	**SL 40**	**SL 10**	**SL 20**	**SL 30**	**SL 40**
8	Verify METT-TC effects on threat forces			all				10-20 min				
9	Draft threat assessments to develop realistic threat models			all	1-2 hrs							
10	Develop enemy OB/structure – indicate a level of confidence in information you have gathered	A given in FSO mode with known enemy (eg, Korea), 1-2 hrs		FSO	1-2 hrs				every 1-3 mo			
		SSO is ongoing, 1-2 min or more per event, max of 2-3 hrs (very infrequent)		SSO	1-2 min to 2-3 hrs				ongoing			
11	Analyze intelligence holding IOT identify existing or emerging enemy TTPs	FSO is < 1hr. This occurs rarely, 1-2/yr	Success or fail to perform due to lack of investigation or persistence. With IA experience you get better	FSO	20-60 min				1-2 per year			
		SSO is ongoing when you get a new piece of info. You must do investigation on each new individual or system (weapon) that shows up.		SSO	2-8 hrs				ongoing			
12	Develop initial ECOAs based upon indicators and historical TTPs	FSO it takes a couple days done prior to deployment. Develop about 3 COAs. Cmdr's discretion and time constrained.	Poor performance is due to being sloppy. Not taking something into consideration. Dropping the ball too many times. An attitude problem.	FSO	12-36 hrs				1-2 per year			
		SSO depends on the enemy. Review of past 30 days to update SA. 1-2 days of focused effort. Become an SME on them for their very recent history. Redo this every 72 hrs or so.		SSO	12-24 hrs				60 - 84 hrs			
13	Develop threat capabilities statement in Full Spectrum is focused on units – a quick analysis and writing one paragraph	Fairly easy, about an hour, dealing with knowns	20/30 level should easily get this 99% always	FSO	~1hr				every day			
13	Develop threat capabilities statement in Stability and Support is focused on individual or small group level sustainment capabilities – requires much more analysis and is ongoing. Use of FMs, TTPs, methods, checklists to guide performance.	Ongoing, time to investigate individuals or weapon system, hrs to days, you run across a higher percentage of surprises which need investigation	Mistakes are made when the checklists are not used when you are not sure of the method. Use of Initiative is what good analysts does if method is not available or known.	SSO	2-8 hrs				ongoing			

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